U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-278 800

Alternatives for Hazardous Waste Management in the Metals Smelting and Refining Industries

Calspan Corp, Buffalo, N Y

Prepared for

Environmental Protection Agency, Washington, D C Office of Solid Waste Management Programs

Mar 77

BIBLIOGRAPHIC DATA SHEET

1. Report No.

2.

PB 278 800

4. Title and Subtitle

Alternatives for Hazardous Waste Management in the Metals Smelting and Refining Industries

5. Report Date
March 1977

6.

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8. Performing Organization Rept. No.

9. Performing Organization Name and Address

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Box 235
Buffalo, N. Y. 14221

10. Project/Task/Work Unit No.

11. Contract/Grant No.
68-01-4312

12. Sponsoring Organization Name and Address

Environmental Protection Agency
Office of Solid Waste, Hazardous Waste Management Division
Washington, D.C. 20460

13. Type of Report & Period Covered
Final

14. 200/01

15. Supplementary Notes

16. Abstracts

This study assesses the alternatives to landfill disposal of potentially hazardous industrial wastes generated by the metals smelting and refining industries, identified by EPA Contract No. 68-01-2604 ("Assessment of Industrial Hazardous Waste Practices in the Metal Smelting and Refining Industry"). The alternatives analyzed include chemical landfill, precipitation, reduction roasting, evaporation, dewatering, and sintering. The processes analyzed identify feasible alternatives that enable materials or energy recovery, waste detoxification or immobilization, and volume reduction for comparison with landfill disposal. Incineration was not a viable option for this industry's wastes and was, therefore, not examined in this study.

17. Key Words and Document Analysis. 17a. Descriptors

Resource recovery, hazardous waste, metal smelting and refining, waste management, landfill, treatment costs, resource recovery costs, cost analysis, chemical landfill, sludge, slag, dust, potliners, reduction roasting, precipitation, evaporation

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

REPRODUCED BY
NATIONAL TECHNICAL INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

18. Availability Statement
Release unlimited

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page
UNCLASSIFIED

21. No. of Pages
253

22. Price
A12, A01

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

ALTERNATIVES FOR HAZARDOUS WASTE MANAGEMENT IN THE METALS SMELTING AND REFINING INDUSTRIES

This final report (SW-153c) describes work performed
for the Federal solid waste management program
under contract no. 68-01-4312
and is reproduced as received from the contractor

U.S. ENVIRONMENTAL PROTECTION AGENCY

1978

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This report was prepared by Calspan Corporation, Buffalo, New York, under Contract No. 68-01-4312.

Publication does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of commercial products constitute endorsement by the U.S. Government.

An environmental protection publication (SW-153c) in the solid waste management series.

ACKNOWLEDGEMENTS

The EPA Project Officer for direction of this program was Mrs. Alexandra G. Tarnay, Office of Solid Waste, Hazardous Waste Management Division.

The Calspan project performance was directed by Messrs. D.B. Dahm and R. J. Pilie, respective heads of the Environmental and Energy Systems Department. The Calspan Project Engineer was Mr. E. Isenberg. Messrs. R.P. Leonard, R.C. Ziegler, A.T. McCord, H.G. Reif, and D.P. Jette provided technical and economic analyses for treatment techniques described in this report.

Consultative services provided by Arthur D. Little, Inc., Cambridge, Massachusetts under the terms of the contract were coordinated through Dr. J. B. Berkowitz, Senior Staff Member.

Appreciation is also extended to the several companies who have provided information and costs for equipment used in the treatment alternatives prepared for this report.

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EXECUTIVE SUMMARY

Several categories of metals smelting and refining industries, whose wastes were classified as potentially hazardous were examined by EPA Contract No. 68-01-2604, "Assessment of Industrial Hazardous Waste Practices in the Metal Smelting and Refining Industry." Alternatives to landfill disposal were evaluated.

1. Iron and steel coke production waste streams 1 and 2, ammonia still sludge and decanter tank tars, generally were found to have no recovered material value.

2. Alternative treatment of iron and steel manufacturing wastes were found to be in several general categories. None of the alternative treatments offered definite recovered material values in excess of the treatment costs. The iron and steel air emission control dusts and sludges, waste streams 3, 4, and 5 as well as rolling mill sludge, waste stream 6, were wastes with potential, but not definite, recovered material values in excess of alternative treatment costs. The spent pickle liquor, waste stream 8, alternative processes, while recovering useful materials, did not provide recovery values exceeding alternative treatment costs.

3. The ferroalloy industry had one waste stream, ferrochrome slag, (waste stream 12A), with potential recovered material value exceeding alternative treatment costs. The remaining wastes contained recoverable materials whose value did not exceed alternative treatment costs. These were ferro and silicomanganese slags, waste streams 13 and 14. Waste stream 11, ferrosilicon dusts, did not have any recoverable materials.

4. Generally, only the primary nonferrous smelting and refining industry, as opposed to the secondary, had potentially hazardous wastes with definite recovery value exceeding alternative treatment costs. The major exception was the primary antimony, electrolytic and pyrometallurgical, waste streams 23 and 24, which did not have recovery value.

5. All of the secondary nonferrous smelting and refining industries generated wastes without recovered material values. These were waste stream 27, copper refining blast furnace slag; 28, lead refining SO_2 scrubwater sludge; and 29, aluminum refining scrubber sludge. The one exception was waste 30, secondary aluminum high salt slag, which offered potential recovered material value exceeding alternative treatment costs.

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Alternative Waste Treatment and Material Recovery Costs. Capital and annual costs for alternative waste treatment and material recovery in the metal manufacturing operations considered in this study are based on a typical plant and are expressed in 1976 dollars.

The information concerning alternative waste treatment costs for the industries considered are summarized in Table 1. Implementation of the alternative processes results in net gains for six of the waste streams; i.e., the value assigned to the recovered material exceeds the cost of installing and operating the alternative waste treatment system. These waste streams are:

1. Primary lead smelting sludge, waste stream 17.
2. Primary electrolytic zinc sludge, waste stream 18.
3. Primary pyrometallurgical zinc sludge, waste stream 19.
4. Primary aluminum scrubber sludges, spent pot liners and skimmings, waste streams 20 and 21.
5. Primary titanium chlorinator condenser sludge, waste stream 25.

Twenty-one waste streams have alternative treatment costs (net costs where applicable) that were less than \$5 per metric ton (\$4.50/short ton) of product. (Alternative treatment costs in \$ per metric ton of waste are also shown in Table 1.) These are:

1. Sulfuric acid waste pickle liquor, waste stream 8A-\$4.87
2. Secondary aluminum scrubwater sludge, waste stream 29 - \$4.15
3. Secondary lead scrubwater sludge, waste stream 28 - \$3.84
4. Ferrochrome dust, waste stream 12 - \$2.85
5. Copper smelting, acid plant blowdown sludge, waste stream 15 - \$2.85
6. Electrolytic copper mixed sludge, waste stream 16 - \$2.48
7. Hydrochloric acid waste pickle liquor, waste stream 8B - \$1.33
8. Primary aluminum shot blast and cast house dusts, waste stream 22 - \$0.54
9. Primary zinc pyrometallurgical dust, waste stream 19 - \$0.31
10. Primary zinc electrolytic sludge, waste stream 18 - \$0.29

Table 1 Summary of Alternative Waste Treatment Costs

Waste Stream	Number	$/Metric Ton of Waste				$/Metric Ton of Product	
		Wet		Dry			
		Total	Net	Total	Net	Total	Net
Iron and Steel Coke Production - Ammonia Still Lime Sludge	1	$ 78.89	$ NRV	$ 259.21	$ NRV	$ 0.07	$ NRV
Iron and Steel Coke Production - Decanter Tank Tar from Coke Production	2	64.58	NRV	324.09	NRV	0.71	NRV
Iron and Steel Prod. - Basic Oxygen Furnace - Wet Emission Control Unit Sludge	3	12.66	7.36	29.90	17.40	0.48	0.28
Iron and Steel Prod.- Open Hearth Furnace - Emission Control Dust	4	12.66	7.36	29.90	17.40	0.48	0.28
Iron and Steel Prod.- Electric Furnace - Wet Emission Control Sludge	5	12.66	7.36	29.90	17.40	0.48	0.28
Iron and Steel Prod.- Rolling Mill Sludge	6	6.46	1.45	16.25	3.65	0.03	0.006
Iron and Steel Prod.- Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	7A	6.85	NRV	27.40	NRV	0.004	NRV

See page 7 for legend.

Table 1 (Cont.) Summary of Alternative Waste Treatment Costs

		$/Metric Ton of Waste				$/Metric Ton of Product	
		Wet		Dry			
Waste Stream	**Number**	Total	Net	Total	Net	Total	Net
Iron and Steel Prod.- Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (HCl)	7B	$ 6.77	$ NRV	$ 67.67	$ NRV	$ 0.003	$ NRV
Iron and Steel Prod.- Cold Rolling Mill - Waste Pickle Liquor - Sulfuric Acid (H_2SO_4)	8A	55.54	43.31	1,365.82	1,065.24	6.24	4.87
Iron and Steel Prod.- Cold Rolling Mill - Waste Pickle Liquor - Hydrochloric Acid (HCl)	8B	38.38	24.80	449.78	290.63	2.06	1.33
Iron and Steel Prod.- Galvanizing Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	9A	0.99	NRV	3.19	NRV	0.04	NRV
Iron and Steel Prod.- Galvanizing Mill - Acid Rinsewater Neutralization Sludge (HCl)	9B	3.74	NRV	12.47	NRV	0.03	NRV
Ferroalloys - Ferrosilicon Manufacture - Miscellaneous Dusts	11	N.A.	N.A.	15.88	NRV	5.36	NRV

See page 7 for legend.

Table 1 (Cont.) Summary of Alternative Waste Treatment Costs

		$/Metric Ton of Waste				$/Metric Ton of Product	
		Wet		Dry			
Waste Stream	Number	Total	Net	Total	Net	Total	Net
Ferroalloys - Ferrosilicon Manufacture - Slag	12A	$ N.A.	$ N.A.	$ 3.91	$ 2.91	$ 6.85	$ 5.10
Ferroalloys - Ferrosilicon Manufacture - Dust	12B	N.A.	N.A.	18.82	NRV	2.85	NRV
Ferroalloys - Ferrosilicon Manufacture - Sludge	12C	13.88	NRV	34.56	NRV	5.23	NRV
Ferroalloys - Silicomanganese Manufacture - Slag and Scrubber Sludge	13	20.36	18.79	50.80	46.88	15.07	13.91
Ferroalloys - Ferromanganese Manufacture - Slag and Sludge	14	20.36	18.79	50.80	46.88	15.07	13.91
Copper Smelting - Acid Plant Blowdown Sludge	15	379.27	NRV	884.97	NRV	2.65	NRV
Electrolytic Copper Refining - Mixed Sludge	16	360.40	NRV	991.13	NRV	2.48	NRV
Lead Smelting - Sludge	17	6.80	1.01*	22.61	3.36*	1.34	0.20*

See page 7 for legend.

Table 1 (Cont.) Summary of Alternative Waste Treatment Costs

Waste Stream	Number	$/Metric Ton of Waste				$/Metric Ton of Product	
		Wet		Dry			
		Total	Net	Total	Net	Total	Net
Electrolytic Zinc Manufacture	18	$ 16.81	$ 3.50*	$ 56.25	$ 11.20*	$ 1.46	$ 0.29*
Pyrometallurgical Zinc Manufacture - Sludges - Primary Gas Cleaning and Acid Plant Blowdown	19A	3.56	15.44*	11.78	51.08*	1.43	6.21*
Pyrometallurgical Zinc Manufacture - Sludges - Retort Gas Scrubber Bleed	19B	15.30	NRV	30.59	NRV	0.31	NRV
Aluminum Manufacture-Scrubber Sludges	20	35.09	18.35*	27.63	40.59*	13.65	7.14*
Aluminum Manufacture - Spent Potliners and Skimmings	21	35.09	18.35*	27.63	40.59*	13.65	7.14*
Aluminum Manufacture - Shot Blast and Cast House Dusts	22	N.A.	N.A.	75.33	NRV	0.54	NRV

See page 7 for legend.

Table 1 (Cont.) Summary of Alternative Waste Treatment Costs

		$/Metric Ton of Waste				$/Metric Ton of Produce	
		Wet		Dry			
Waste Stream	Number	Total	Net	Total	Net	Total	Net
Pyrometallurgical Antimony Manufacture-Blast Furnace Slag	23	$ N.A.	$ N.A.	$ 18.40	$ NRV	$ 52.48	$ NRV
Electrolytic Antimony Manufacture - Spent Anolyte Sludge	24	55.05	NRV	165.15	NRV	36.70	NRV
Titanium Manufacture-Chlorinator Condenser Sludge	25	12.53	14.85*	31.59	37.41*	10.39	12.31*
Copper Refining - Blast Furnace Slag	27	N.A.	N.A.	37.86	NRV	13.25	NRV
Lead Refining - SO_2 Scrubwater Sludge	28	25.61	NRV	85.36	NRV	3.84	NRV
Aluminum Refining - Scrubber Sludge	29	16.59	NRV	55.29	NRV	4.15	NRV
Aluminum Refining - High Salt Slag	30	N.A.	N.A.	47.89	26.02	67.04	36.43

N.A. = Not applicable
* = Net gain, i.e., value of recovered material exceeds cost of alternative treatment
NRV = No recovery value

11. Steel mill air emission, waste streams 3, 4, and 5 - $0.28

12. Primary lead smelting sludge, waste stream 17 - $0.20

13. Galvanizing mill acid rinsewater neutralizing sludge, waste stream 9A - 0.04

14. Galvanizing mill acid rinsewater neutralizing sludge, waste stream 9B - $0.03

15. Iron and steel rolling mill sludge, waste stream 6 - $0.006

16. Cold rolling mill acid rinsewater neutralization sludge, waste stream 7A - $0.004

17. Cold rolling mill acid rinsewater neutralization sludge, waste stream 7B - $0.003

18. Ammonia still sludge, waste stream 1

19. Decanter tank tar, waste stream 2

Nine waste streams show alternative treatment costs (net costs where applicable) of more than $5 per metric ton ($4.50/short ton) of product. These are:

1. Primary pyrometallurgical antimony slag, waste stream 23 - $52.48

2. Primary electrolytic antimony sludge, waste stream 24 - $36.70

3. Secondary aluminum refining high salt slag, waste stream 30 - $36.43

4. Silico and ferromanganese slag and sludge, waste streams 13 and 14 - $13.91

5. Secondary copper refining slag, waste stream 27 - $13.25

6. Ferrosilicon dust, waste stream 11 - $5.36

7. Ferrochrome sludge, waste stream 12C - $5.23

8. Ferrochrome slag, waste stream 12A - $5.10

Value of Recovered Materials Versus Alternative Treatment Costs (Break-even Analysis). In summary, six alternative treatment processes yield recovered materials whose value exceeds the alternative treatment costs of operation; 18 processes do not provide materials with discernible market values. Of the remaining seven alternative processes, four can be expected to reach a break-even point and three cannot.

Wastes with definite recovered material value exceeding alternative treatment costs:

1. Primary lead smelting sludge, waste stream 17
2. Primary electrolytic zinc sludge, waste stream 18
3. Primary pyrometallurgical zinc sludge, waste stream 19A
4. Primary aluminum scrubber sludge, potliners and skimmings, waste streams 20 and 21
5. Primary titanium chlorinator condenser sludge, waste stream 25

Wastes with potential recovered material value exceeding alternative treatment costs:

1. Steel mill emission control sludge and dusts, waste streams 3, 4, and 5
2. Rolling mill sludge, waste stream 6
3. Slag from ferrochrome manufacture, waste stream 12A
4. Secondary aluminum high salt slag, waste stream 30

Wastes with recovered materials whose value does not exceed alternative treatment costs:

1. Silico and ferromanganese slag and sludge, waste streams 13 and 14
2. Spent sulfuric acid pickle liquor, waste stream 8A
3. Spent hydrochloric acid pickle liquor, waste stream 8B

Wastes whose alternative treatments do not provide recovered materials:

1. Ammonia still sludge, waste stream 1
2. Decanter tank tar, waste stream 2

3. Sulfuric acid rinsewater neutralization sludge, waste stream 7A

4. Hydrochloric acid rinsewater neutralization sludge, waste stream 7B

5. Sulfuric acid spent pickle liquor, waste stream 9A

6. Hydrochloric acid spent pickle liquor, waste stream 9B

7. Ferrosilicon - misc. dusts, waste stream 11

8. Dust from ferrochrome manufacturing, waste stream 12B

9. Sludge from ferrochrome manufacturing, waste stream 12C

10. Copper smelting acid plant blowdown, waste stream 15

11. Electrolytic copper refining - mixed sludge, waste stream 16

12. Pyrometallurgical zinc sludge (primary), waste stream 19B

13. Primary aluminum shot blast and cast house dust, waste stream 22

14. Primary antimony blast furnace slag, waste stream 23

15. Primary antimony spent anolyte sludge, waste stream 24

16. Secondary copper blast furnace slag, waste stream 27

17. Secondary lead SO_2 scrubwater sludge, waste stream 28

18. Secondary aluminum scrubber sludge, waste stream 29

The total annual costs and the break-even analyses of the alternative treatment processes by comparison to the value of recoverable materials are summarized in Table 2 . The percent of market value assigned to each recoverable material is also shown in Table 2 .

Benefits Derived from Alternative Treatment Systems. The major processes used by the alternative treatment systems and the benefits therefrom are summarized in Table 3 .

Table 2 Break-Even Analysis Between Alternative Treatment Cost and Recoverable Resource Value

Waste Stream	Number	Total Annual Cost	Annual Value of Recovered Material	Percent of Market Price Assigned	Net Annual Cost	Required Percent Increase in Recovered Material Value
Iron and Steel Coke Prod. - Ammonia Still Lime Sludge	1	$ 181,450	$ NRV	N.A.	$ N.A.	N.A.
Iron and Steel Coke Prod. - Decanter Tank Tar from Coke Production	2	1,882,410	NRV	N.A.	N.A.	N.A.
Iron and Steel Production - Basic Oxygen Furnace - Wet Emission Control Unit Sludge	3	1,195,950	500,000	100[a]	695,950	139
Iron and Steel Production - Open Hearth Furnace - Emission Control Dust	4	1,195,950	500,000	100[a]	695,950	139
Iron and Steel Production - Electric Furnace - Wet Emission Control Sludge	5	1,195,950	500,000	100[a]	695,950	139
Iron and Steel Production - Rolling Mill Sludge	6	50,370	39,060	100[a]	11,310	29

See page 16 for legend.

Table 2 (Cont.) Break-Even Analysis Between Alternative Treatment Cost and Recoverable Resource Value

Waste Stream	Number	Total Annual Cost	Annual Value of Recovered Material	Percent of Market Price Assigned	Net Annual Cost	Required Percent Increase in Recovered Material Value
Iron and Steel Production - Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	7A	$ 2,740	NRV	$ N.A.	$ N.A.	N.A.
Iron and Steel Production - Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (HCl)	7B	2,740	NRV	N.A.	N.A.	N.A.
Iron and Steel Production - Cold Rolling Mill - Waste Pickle Liquor - Sulfuric Acid (H_2SO_4)	8A	4,370,620	961,840	100[b]	3,408,780	354
Iron and Steel Production - Cold Rolling Mill - Waste Pickle Liquor - Hydrochloric Acid (HCl)	8B	1,439,280	509,280	70[c],100[a]	930,000	183
Iron and Steel Production - Galvanizing Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	9A	4,470	NRV	N.A.	N.A.	N.A.

See page 16 for legend.

Table 2 (Cont.) Break-Even Analysis Between Alternative Treatment Cost and Recoverable Resource Value

Waste Stream	Number	Total Annual Cost	Annual Value of Recovered Material	Percent of Market Price Assigned	Net Annual Cost	Required Percent Increase in Recovered Material Value
Iron and Steel Production - Galvanizing Mill - Acid Rinsewater Neutralization Sludge (HCl)	9B	$ 3,740	$ NRV	N.A.	$ N.A.	N.A.
Ferroalloys - Ferrosilicon Manufacture - Miscellaneous Dusts	11	214,400	NRV	N.A.	N.A.	N.A.
Ferroalloys - Ferrosilicon Manufacture - Slag	12A	239,690	61,300	100[d]	178,390	291
Ferroalloys - Ferrosilicon Manufacture - Dust	12B	99,750	NRV	N.A.	N.A.	N.A.
Ferroalloys - Ferrosilicon Manufacture - Sludge	12C	183,150	NRV	N.A.	N.A.	N.A.
Ferroalloys - Silicomanganese Manufacture - Slag and Scrubber Sludge	13	452,090	34,880	25[e]	417,210	1,196

See page 16 for legend.

Table 2 (Cont.) Break-Even Analysis Between Alternative Treatment Cost and Recoverable Resource Value

Waste Stream	Number	Total Annual Cost	Annual Value of Recovered Material	Percent of Market Price Assigned	Net Annual Cost	Required Percent Increase in Recovered Material Value
Ferroalloys - Ferromanganese Manufacture - Slag and Sludge	14	$ 452,090	$ 34,880	25	$ 417,210	1,196
Copper Smelting - Acid Plant Blowdown Sludge	15	265,490	NRV	N.A.	N.A.	N.A.
Electrolytic Copper Refining - Mixed Sludge	16	396,450	NRV	N.A.	N.A.	N.A.
Lead Smelting - Sludge	17	146,970	168,780	25[f]	21,810*	N.A.
Electrolytic Zinc Manufacture	18	146,240	117,100	25[g]	29,140*	N.A.
Pyrometallurgical Zinc Manufacture - Sludges - Primary Gas Cleaning and Acid Plant Blowdown	19A	153,180	817,220	100[g]	(664,040)	N.A.
Pyrometallurgical Zinc Manufacture - Sludges - Retort Gas Scrubber Bleed	19B	33,650	NRV	N.A.	N.A.	N.A.

See page 16 for legend.

Table 2 (Cont.) Break-Even Analysis Between Alternative Treatment Cost and Recoverable Resource Value

Waste Stream	Number	Total Annual Cost	Annual Value of Recovered Material	Percent of Market Price Assigned	Net Annual Cost	Required Percent Increase in Recovered Material Value
Aluminum Manufacture - Scrubber Sludges	20	$2,099,140	$3,180,000	100[h]	$1,091,860	N.A.
Aluminum Manufacture - Spent Potliners and Skimmings	21	2,099,140	3,180,000	100[h]	1,091,860	N.A.
Aluminum Manufacture - Shot Blast and Cast House Dusts	22	82,860	NRV	N.A.	N.A.	N.A.
Pyrometallurgical Antimony Manufacture - Blast Furnace Slag	23	141,700	NRV	N.A.	N.A.	N.A.
Electrolytic Antimony Manufacture - Spent Anolyte Sludge	24	33,030	NRV	N.A.	N.A.	N.A.
Titanium Manufacture - Chlorinator Condenser Sludge	25	78,970	172,500	100[i]	93,530*	N.A.
Copper Refining - Blast Furnace Slag	27	132,510	NRV	N.A.	N.A.	N.A.

See page 16 for legend.

Table 2 (Cont.) Break-Even Analysis Between Alternative Treatment Cost and Recoverable Resource Value

Waste Stream	Number	Total Annual Cost	Annual Value of Recovered Material	Percent of Market Price Assigned	Net Annual Cost	Required Percent Increase in Recovered Material Value
Lead Refining - SO_2 Scrubwater Sludge	28	$ 38,410	$ NRV	N.A.	$ N.A.	N.A.
Aluminum Refining - Scrubber Sludge	29	82,930	NRV	N.A.	N.A.	N.A.
Aluminum Refining - High Salt Slag	30	670,390	306,050	25[j]	364,340	119

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* = Net gain, i.e., value of recovered material exceeds cost of alternative waste treatment
N.A. = Not applicable
NRV = No recovery value

[a] - for iron pellets
[b] - for ferric chloride
[c] - for hydrochloric acid
[d] - for roadfill
[e] - for zinc oxide
[f] - for lead
[g] - for zinc
[h] - for cryolite
[i] - for rutile
[j] - for potassium chloride

Table 3 Summary Table of Alternate Treatment Systems, Benefits, Stage of Development, and Costs

		Alternative Treatment				$/Metric Ton of Waste				$/Metric Ton of Product	
						Wet		Dry			
Waste Stream	Number	Process	Process Category	Development Stage	Benefits Derived	Total	Net	Total	Net	Total	Net
Iron and Steel Coke Production - Ammonia Still Lime Sludge	1	Disposal	P	V	Detoxified, inert solids suitable for chemical landfill	$ 78.89	$ NRV	$ 259.21	$ NRV	$ 0.07	$ NRV
Iron and Steel Coke Production - Decanter Tank Tar from Coke Production	2	Disposal	P	V	Detoxified, inert solids suitable for chemical landfill	64.58	NRV	324.09	NRV	0.71	NRV
Iron and Steel Prod. - Basic Oxygen Furnace - Wet Emission Control Unit Sludge	3	Reduction Roasting	C	V	Ferric oxide recovery for recycle. Lead and zinc oxide recovery for sale.	12.66	7.36	29.90	17.40	0.48	0.28
Iron and Steel Prod.- Open Hearth Furnace - Emission Control Dust	4	Reduction Roasting	C	V	Ferric oxide recovery for recycle. Lead and zinc oxide recovery for sale.	$ 12.66	$ 7.36	$ 29.90	$ 17.40	$ 0.48	$ 0.28
Iron and Steel Prod.- Electric Furnace - Wet Emission Control Sludge	5	Reduction Roasting	C	V	Ferric oxide recovery for recycle. Lead and zinc oxide recovery for sale.	12.66	7.36	29.90	17.40	0.48	0.28
Iron and Steel Prod.- Rolling Mill Sludge	6	Sintering	P	V	Iron recovery for recycle	6.46	1.45	16.25	3.65	0.03	0.006
Iron and Steel Prod.- Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	7A	Dissolution	C	V	Ferric oxide recovery	6.85	NRV	27.40	NRV	0.004	NRV
Iron and Steel Prod.- Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (HCl)	7B	Dissolution	C	V	Ferric chloride recovery	6.77	NRV	67.67	NRV	0.003	NRV
Iron and Steel Prod.- Cold Rolling Mill - Waste Pickle Liquor - Sulfuric Acid (H_2SO_4)	8A	Precipitation	C	III	Ferric chloride for sale, Calcium sulfate (gypsum) for chemical landfill	55.54	43.31	1,365.82	1,065.24	6.24	4.87
Iron and Steel Prod.- Cold Rolling Mill - Waste Pickle Liquor - Hydrochloric Acid (HCl)	8B	Volatilization Reduction Roasting	P C	IV IV	Hydrochloric acid recovered for recycle Ferric oxide recovered for reuse	38.38	24.80	449.78	290.63	2.06	1.33
Iron and Steel Prod.- Galvanizing Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	9A	Dissolution	C	V	Ferric oxide recovered	$ 0.99	$ NRV	$ 3.19	$ NRV	$ 0.04	$ NRV
Iron and Steel Prod.- Galvanizing Mill - Acid Rinsewater Neutralization Sludge (HCl)	9B	Dissolution	C	V	Ferric chloride recovery	3.74	NRV	12.47	NRV	0.03	NRV

Table 3 Summary Table of Alternate Treatment Systems, Benefits, Stage of Development, and Costs (Cont.)

Waste Stream	Number	Alternative Treatment Process	Alternative Treatment Process Category	Development Stage	Benefits Derived	$/Metric Ton of Waste, Wet, Total	$/Metric Ton of Waste, Wet, Net	$/Metric Ton of Waste, Dry, Total	$/Metric Ton of Waste, Dry, Net	$/Metric Ton of Product, Total	$/Metric Ton of Product, Net
Ferroalloys - Ferrosilicon Manufacture - Miscellaneous Dusts	11	Disposal	P	-	Chemical landfill	N.A.	N.A.	15.88	NRV	5.36	NRV
Ferroalloys - Ferrosilicon Manufacture - Slag	12A	Precipitation	C	V	Detoxification	N.A.	N.A.	3.91	2.91	6.85	5.10
Ferroalloys - Ferrosilicon Manufacture - Dust	12B	Precipitation	C	V	Detoxification	N.A.	N.A.	18.82	NRV	2.85	NRV
Ferroalloys - Ferrosilicon Manufacture - Sludge	12C	Precipitation	C	V	Detoxification	13.88	NRV	34.56	NRV	5.23	NRV
Ferroalloys - Silicomanganese Manufacture - Slag and Scrubber Sludge	13	Reduction Roasting	C	IV	Ferro and silicomanganese for recycle	20.36	18.79	50.80	46.88	15.07	13.91
Ferroalloys - Ferromanganese Manufacture - Slag and Sludge	14	Reduction Roasting	C	IV	Lead and zinc oxide for sale	20.36	18.79	50.80	46.88	15.07	13.91
Copper Smelting - Acid Plant Blowdown Sludge	15	Precipitation	C	V	Detoxification	$379.27	$ NRV	$ 884.97	$ NRV	$ 2.65	$ NRV
Electrolytic Copper Refining - Mixed Sludge	16	Precipitation	C	V	Detoxification	360.40	NRV	991.13	NRV	2.48	NRV
Lead Smelting - Sludge	17	Sintering	P	V	Lead recycled for reprocessing	6.80	1.01*	22.61	3.36*	1.34	0.20*
Electrolytic Zinc Manufacture	18	Precipitation	C	V	Zinc recycled for reprocessing	16.81	3.50*	56.25	11.20*	1.46	0.29*
Pyrometallurgical Zinc Manufacture - Sludges - Primary Gas Cleaning and Acid Plant Blowdown	19A	Sintering	P	V	Zinc recycled for reuse	3.56	15.44*	11.78	51.08*	1.43	6.21*
Pyrometallurgical Zinc Manufacture - Sludges - Retort Gas Scrubber Bleed	19B	Centrifuge	P	V	Zinc recycled for reuse	15.30	NRV	30.59	NRV	0.31	NRV
Aluminum Manufacture-Scrubber Sludges	20	Precipitation Evaporation Dewatering Drying Disposal	P,C	V	Cryolite recovered for reuse	35.09	18.35*	27.63	40.59*	13.65	7.14*
Aluminum Manufacture - Spent Potliners and Skimmings	21		P,C	V	Cryolite recovered for reuse	35.09	18.35*	27.63	40.59*	13.65	7.14*
Aluminum Manufacture - Shot Blast and Cast House Dusts	22	Precipitation	C	V	Detoxification	N.A.	N.A.	75.33	NRV	0.54	NRV

Table 3 Summary Table of Alternate Treatment Systems, Benefits, Stage of Development, and Costs (Cont.)

		Alternative Treatment				$/Metric Ton of Waste				$/Metric Ton of Product	
						Wet		Dry			
Waste Stream	Number	Process	Process Category	Development Stage	Benefits Derived	Total	Net	Total	Net	Total	Net
Pyrometallurgical Antimony Manufacture-Blast Furnace Slag	23	Precipitation	C	V	Detoxification	$ N.A.	$ N.A.	$ 18.40	$ NRV	$ 52.48	$ NRV
Electrolytic Antimony Manufacture - Spent Anolyte Sludge	24	Disposal	P	-	Detoxification	55.05	NRV	165.15	NRV	36.70	NRV
Titanium Manufacture-Chlorinator Condenser Sludge	25	Centrifuge Dewatering Recycling	P	III	Titanium dioxide (rutile) and carbon recovered for reuse	12.53	14.85*	31.59	37.41*	10.39	12.31*
Copper Refining - Blast Furnace Slag	27	Precipitation	C	V	Detoxification	N.A.	N.A.	37.86	NRV	13.25	NRV
Lead Refining - SO_2 Scrubwater Sludge	28	Precipitation	C	V	Detoxification	25.61	NRV	85.36	NRV	3.84	NRV
Aluminum Refining - Scrubber Sludge	29	Centrifuge Dewatering	P	V	Volume reduction	16.59	NRV	55.29	NRV	4.15	NRV
Aluminum Refining - High Salt Slag	30	Crushing & Screening, Dewatering & Drying	P	IV	Aluminum oxide recovered for reuse	N.A.	N.A.	47.89	26.02	67.04	36.43
		Dissolution Evaporation Dewatering Drying	P,C	IV	Flux salts, sodium and potassium chloride						

Alternative Treatment Unit Process Category:

P. - Physical
C. - Chemical

Alternative Treatment Stage of Development:

I Process is not applicable for this waste
II Process needs research effort, might work in 5-10 years
III Process appears useful for hazardous wastes but needs development work
IV Process is developed but not commonly used for hazardous wastes
V Process common to most industrial waste processors

N.A. - Not applicable

* - Net gain, i.e., value of recovered material exceeds cost of alternative treatment

NRV - No recovery value

Cost Comparison of Alternative Treatment Processes and Landfills. The costs for alternative treatment processes and landfill are shown in Table 4. The costs are relative and are expressed as ratios with the cost of sanitary landfill without containerization used as the denominator. The comparison is made in terms of cost per metric ton of product. The lowest cost alternative is designated for each waste.

As would be expected, the costs of sanitary landfill with containerization and chemical landfill are always higher than sanitary landfill without containerization costs. In two cases, Waste Nos. 1 and 7, the sanitary landfill cost with containerization is the same as the chemical landfill cost. These cases are characterized by large annual productions and relatively small quantities of wastes. Containerization represents the dominant cost.

Sanitary landfill is the least cost alternative for 15 wastes when liquids are not containerized.

Chemical landfilling because of the requirement to containerize liquid wastes and its inherent higher costs does not provide any least cost waste candidates.

Alternative treatment processes,excluding recovery values (total), offer least costs for six of the wastes with one of these, pyrometallurgical zinc retort gas scrubber bleed, waste stream 19, at par with sanitary landfilling without containerization.

Alternative treatment processes, where recovery values were included (net), offer least cost possibilities for eight of the wastes.

Table 4 Relative Costs for Landfill and Alternative Treatment Process (Per Unit of Product)

Waste Stream	Number	Sanitary Landfill W/O Contain.	Sanitary Landfill With Contain.	Chemical Landfill	Alternative Treatment Process Total	Alternative Treatment Process Net
Iron and Steel Coke Production - Ammonia Still Lime Sludge	1	1	3.50	3.50	3.5	NRV
Iron and Steel Coke Production - Decanter Tank Tar from Coke Production	2	1	5.75	5.92	35.5	NRV
Iron and Steel Production - Basic Oxygen Furnace - Wet Emission Control Unit Sludge	3	1	3.83	4.35	0.74	0.43
Iron and Steel Production - Open Hearth Furnace - Emission Control Dust	4	1	3.83	4.35	0.74	0.43
Iron and Steel Production - Electric Furnace - Wet Emission Control Sludge	5	1	3.83	4.35	0.74	0.43
Iron and Steel Production - Rolling Mill Sludge	6	1	4.40	4.80	0.60	0.12
Iron and Steel Production - Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	7A	1	4.00	4.00	0.40	NRV

See page 25 for legend.

Table 4 Relative Costs for Landfill and Alternative Treatment Process (Per Unit of Product) (Cont.)

Waste Stream	Number	Sanitary Landfill W/O Contain.	Sanitary Landfill With Contain.	Chemical Landfill	Alternative Treatment Process Total	Alternative Treatment Process Net
Iron and Steel Production - Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (HCl)	7B	1	4.00	4.00	0.30	NRV
Iron and Steel Production - Cold Rolling Mill - Waste Pickle Liquor - Sulfuric Acid (H_2SO_4)	8A	1	5.98	6.19	4.88	3.80
Iron and Steel Production - Cold Rolling Mill - Waste Pickle Liquor - Hydrochloric Acid (HCl)	8B	1	5.97	6.16	3.38	2.18
Iron and Steel Production - Galvanizing Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	9A	1	3.59	3.85	0.07	NRV
Iron and Steel Production - Galvanizing Mill - Acid Rinsewater Neutralization Sludge (HCl)	9B	1	3.25	3.55	0.15	NRV
Ferroalloys - Ferrosilicon Manufacture - Miscellaneous Dusts	11	1	N.A.	1.20	1.91	NRV
Ferroalloys - Ferrosilicon Manufacture - Slag	12A	1	N.A.	1.20	0.53	0.40

See page 25 for legend.

Table 4 Relative Costs for Landfill and Alternative Treatment Process (Per Unit of Product) (Cont.)

Waste Stream	Number	Sanitary Landfill W/O Contain.	Sanitary Landfill With Contain.	Chemical Landfill	Alternative Treatment Process Total	Alternative Treatment Process Net
Ferroalloys - Ferrosilicon Manufacture - Dust	12B	1	N.A.	1.20	2.28	NRV
Ferroalloys - Ferrosilicon Manufacture - Sludge	12C	1	6.00	6.20	1.33	NRV
Ferroalloys - Silicomanganese Manufacture - Slag and Scrubber Sludge	13	1	2.70	3.45	1.02	0.95
Ferroalloys - Ferromanganese Manufacture - Slag and Sludge	14	1	2.70	3.45	1.02	0.95
Copper Smelting - Acid Plant Blowdown Sludge	15	1	3.18	3.47	15.59	NRV
Electrolytic Copper Refining - Mixed Sludge	16	1	3.33	3.58	20.67	NRV
Lead Smelting - Sludge	17	1	5.99	6.19	0.65	*
Electrolytic Zinc Manufacture	18	1	5.03	5.22	1.40	*
Pyrometallurgical Zinc Manufacture - Sludges - Primary Gas Cleaning and Acid Plant Blowdown	19A	1	5.99	6.19	0.40	*

See page 25 for legend.

Table 4 Relative Costs for Landfill and Alternative Treatment Process (Per Unit of Product) (Cont.)

Waste Stream	Number	Sanitary Landfill W/O Contain.	Sanitary Landfill With Contain.	Chemical Landfill	Alternative Treatment Process Total	Alternative Treatment Process Net
Pyrometallurgical Zinc Manufacture - Sludges - Retort Gas Scrubber Bleed	19B	1	3.26	3.55	1.00	NRV
Aluminum Manufacture - Scrubber Sludges	20	1	5.20	5.54	3.49	*
Aluminum Manufacture - Spent Potliners and Skimmings	21	1	5.20	5.54	3.49	*
Aluminum Manufacture - Shot Blast and Cast House Dusts	22	1	N.A.	1.33	3.00	NRV
Pyrometallurgical Antimony Manufacture - Blast Furnace Slag	23	1	N.A.	1.25	1.70	NRV
Electrolytic Antimony Manufacture-Spent Anolyte Sludge	24	1	3.23	3.52	2.62	NRV
Titanium Manufacture - Chlorinator Condenser Sludge	25	1	4.29	4.53	0.80	*
Copper Refining - Blast Furnace Slag	27	1	N.A.	1.26	2.78	NRV
Lead Refining - SO_2 Scrubwater Sludge	28	1	3.27	3.54	1.12	NRV

See page 25 for legend.

Table 4 Relative Costs for Landfill and Alternative Treatment Process (Per Unit of Product) (Cont.)

Waste Stream	Number	Sanitary Landfill W/O Contain.	Sanitary Landfill With Contain.	Chemical Landfill	Alternative Treatment Process	
					Total	Net
Aluminum Refining - Scrubber Sludge	29	1	3.56	3.84	1.36	NRV
Aluminum Refining - High Salt Slag	30	1	N.A.	1.20	6.38	3.47

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* = is used to denote that the alternative treatment process results in a net gain.
___ = least cost alternative
N.A.= Not applicable
NRV = No recovery value

INTRODUCTION

A study for the U.S. EPA under Contract No. 68-01-2604 has been completed to assess the waste generation, treatment and disposal practices in the primary and secondary metals smelting and refining industries. Potentially hazardous wastes generated by these industries have been identified by that report.

This study assesses alternatives to sanitary landfill disposal of these potentially hazardous wastes. The processes analyzed identify feasible alternatives that enable materials or energy recovery, waste detoxification or immobilization and volume reduction for comparison with landfill disposal.

The alternatives analyzed which have potential for treating hazardous wastes are the physical, chemical, and biological processes which have been identified under EPA Contract No. 68-01-2288.

The potentially hazardous waste streams considered in this study were:

	Waste Stream Number
Ferrous Metal Smelting and Refining Potentially Hazardous Wastes	
A. Iron and Steel Coke Production	
1. Ammonia Still Lime Sludge	1
2. Decanter Tank Tar from Coke Production	2
B. Iron and Steel Production	
1. Basic Oxygen Furnace - Wet Emission Control Unit Sludge	3
2. Open Hearth Furnace - Emission Control Dust	4
3. Electric Furnace - Wet Emission Control Sludge	5
4. Rolling Mill Sludge	6
5. Cold Rolling Mill - Acid Rinsewater Neutralization Sludge	7
6. Cold Rolling Mill - Waste Pickle Liquor	8
7. Galvanizing Mill - Acid Rinsewater Neutralization Sludge	9

Waste Stream Number

C. Ferroalloys

1. Ferrosilicon Manufacture - Miscellaneous Dusts 11
2. Ferrochrome Manufacture - Slag, Dust, and Sludge 12
3. Silicomanganese Manufacture - Slag and Scrubber Sludge 13
4. Ferromanganese Manufacture - Slag and Sludge 14

Primary Nonferrous Smelting and Refining Potentially Hazardous Wastes

A. Copper Smelting-Acid Plant Blowdown Sludge 15

B. Electrolytic Copper Refining - Mixed Sludge 16

C. Lead Smelting - Sludge 17

D. Electrolytic Zinc Manufacture - Sludge 18

E. Pyrometallurgical Zinc Manufacture - Sludges 19

F. Aluminum Manufacture

1. Scrubber Sludges 20
2. Spent Potliners and Skimmings 21
3. Shot Blast and Cast House Dusts 22

G. Pyrometallurgical Antimony Manufacture - Blast Furnace Slag 23

H. Electrolytic Antimony Manufacture - Spent Anolyte Sludge 24

I. Titanium Manufacture - Chlorinator Condenser Sludge 25

Secondary Nonferrous Refining Potentially Hazardous Wastes

A. Copper Refining - Blast Furnace Slag 27

	Waste Stream Number
B. Lead Refining - SO_2 Scrubwater Sludge	28
C. Aluminum Refining	
1. Scrubber Sludge	29
2. High Salt Slag	30

Note: Waste stream number 10 was omitted from this study because it is normally recycled. Waste stream number 26, smelter slag from primary tin manufacture, was deleted from this study because of insufficient information.

DISCUSSION

The purpose of this study was to assess the alternatives to sanitary landfill disposal (regardless of current practices) of potentially hazardous industrial wastes generated by the metals smelting and refining industries. Processes were identified that lead to materials or energy recovery, waste detoxification, immobilization, and volume reduction. Costs were compared with those for sanitary landfill disposal.

Types of waste processing involved in industrial waste reclamation and recovery may be differentiated as follows:

Regeneration is a process which recovers the waste material in the same form and composition as the original raw material. For example, regeneration of hydrochloric acid from spent steel pickling liquor is accomplished by spraying it into a high temperature chamber in which hydrochloric acid is distilled and subsequently recovered, leaving a solid residue of ferric oxide which is recycled for steel making.

Recovery and reclamation involves extracting one or more components from a waste material leaving the remainder for disposal. As an example, one or more metals may be recovered from a waste material but at the end of the process, remaining residues require treatment and/or disposal.

Recycling implies that the waste material is returned to an industrial process without major processing. For example, ferrous and nonferrous scrap is recycled to the smelting industry with nominal sorting operations but no major processing.

Reuse is similar to recycling except that the waste material is utilized by a consumer different from the waste originator.

The feasibility to regenerate, recover, or reuse waste materials is dependent on many factors, some of which are:

1. Value of recovered material.
2. Location of processing plant.
3. Concentration of recoverable component.
4. Quantity of waste.
5. Availability of a suitable treatment technique to produce a recovered product of sufficient purity for recycle.
6. Recovered material specifications.

7. Where the costs for reclamation are economical by comparison with the purchase of new raw materials or to the costs of alternative treatment and disposal procedures.

The major driving force for waste recovery and utilization has been the profit motive. Unless a waste material can be treated to yield a product of sufficient value to cover the costs to produce it, there is no profit motivation and up to the present time the greatest inhibition to recovery has been the economic factor.

The profit motive has persisted for many years and has dictated the manner of industrial waste disposal and whether or not resource recovery is practiced. These attitudes, however, are changing due to changing economic conditions, resource depletion and most significantly to increasing awareness of potentially hazardous waste disposal practices. These practices and the need to conserve natural resources will inevitably increase waste disposal costs.

The Resource Conservation and Recovery Act of 1976 expands the Federal role in both the solid waste and resource recovery fields. Regulations and other endeavors required by this act, will have a serious impact on solid waste disposal techniques.

Waste disposal practices have affected the safety and availability of water supplies as attested by numerous reported incidents. Surface water supplies generally receive attention and are regulated by existing federal and state pollution control programs. Groundwater supplies, on the other hand, are not as closely regulated or protected as surface supplies even though quality standards for drinking and other purposes are the same for surface and groundwater supplies. Approximately one half of the U.S. population is served by groundwater and its use is increasing at the rate of 25% per decade.

The wastes of concern in this project generally contain significant leachable concentrations of toxic elements and are, therefore, considered potentially hazardous if handled and disposed haphazardly on land. Disposal methods, whereby waste materials are exposed to rainwater, surface runoff or groundwater, are environmentally unacceptable because toxic elements can be leached into surface or groundwater supplies.

Toxic materials of concern in this study are:

arsenic
cadmium
chromium
copper
nickel
lead
antimony
zinc
mercury
manganese
phenols
selenium
cyanides

Consequently, disposal of wastes containing toxic materials in unlined pits, ponds, and lagoons or in open dumps is a practice that bears close study, examination, and scrutiny.

Since most of the potential toxic elements of concern are heavy metals, the detoxification method used most commonly in this study relies on reaction of the heavy metals with hydroxides. The detoxification reaction forms precipitates of low solubility metal hydroxides which are not readily leached from the waste material. In many instances, we have recommended disposal of the metal hydroxide in a chemical or secure landfill to preclude the mobility of residual soluble fractions remaining in the detoxified waste material. The hydroxide chemicals most commonly used are lime, caustic, and soda ash.

Sulfide precipitation of heavy metals has also been used to achieve lower concentrations, than from hydroxide precipitation, in the soluble fraction of a waste. Sludge disposal of sulfide heavy metal precipitates, however, may result in sulfide oxidation, generation of sulfuric acid and resolubilization of the metals. Sulfide precipitation has been used in conjunction with lime to reduce cadmium levels in those wastes containing cadmium.

In those cases where the filtrates can be recycled, the final concentration of contaminants is not critical, but when the effluents from a treatment operation are discharged from the plant, then the system must be designed to use all practical chemical and physical treatments to meet effluent standards.

Costs were developed for alternative treatment of 33 potentially hazardous wastes generated from metals smelting and refining industries. The alternative treatments were chosen for minimal impact on the environment, for materials or energy recovery, waste detoxification or immobilization and volume reduction. Each waste treatment scheme chosen and described in this report was an alternative to a sanitary landfill as a minimum and to a secure or chemical landfill to preserve and safeguard environmental conditions.

Cost comparisons were then made for the alternative treatment scheme, and for sanitary and chemical landfilling the potentially hazardous wastes. When material recovery was technically feasible, their value was included in the treatment alternative costs. Further examination of these treatment and disposal costs was made by a break-even analyses.

Waste stream number 10, Furnace Emission Sludge from Ferronickel Manufacture, was deleted from the study because it is presently recycled to process and is not disposed. Waste stream number 26, Smelter Slag from Primary Tin Manufacture was also deleted from the study because insufficient information was available on its characteristics.

Production levels, and the quantities and gross physical characteristics of generated wastes are summarized in Table 5 for typical plants.

Table 5 Summary Table of Waste Quantities, Production Values and Gross Physical Characteristics

						Quantity Generated From Typical Plant			
						Weight MT/yr		Volume m^3/yr	
Waste Stream	No.	Typical Plant Production MT/yr	Physical State	Percent Solids	Bulk Density MT/m^3	Dry	Wet	Dry	Wet
Ammonia Still Lime Sludge	1	2,500,000	Sludge	30	1.2	700	2,300	-	1,900
Decanter Tank Tar from Coke Production	2	2,500,000	Sludge	15-30	1.2	5,500	27,600	-	23,000
Basic Oxygen Furnace - Wet Emission Control Unit Sludge	3	2,000,000	Sludge	40	2.0	34,600	86,500	-	43,300
Open Hearth Furnace - Emission Control Dust (4)	4	500,000	Dust	-	1.5	6,900	-	4,600	-
Electric Furnace - Wet Emission Control Sludge	5	500,000	Sludge	40	2.0	4,400	10,900	-	5,400
Rolling Mill Sludge	6	1,800,000	Sludge	40	1.6	3,100	7,800	-	4,900
Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	7A	700,000	Sludge	30	1.2	100	400	-	300
(HCl)	7B	700,000	Sludge	10	1.1	30	300	-	300
Cold Rolling Mill - Waste Pickle Liquor - Sulfuric Acid (H_2SO_4)	8A	700,000	Liquid	20	1.1	3,200	78,700	-	71,500

Table 5 (Cont.) Summary Table of Waste Quantities, Production Values and Gross Physical Characteristics

						Quantity Generated From Typical Plant			
						Weight MT/yr		Volume m^3/yr	
Waste Stream	No.	Typical Plant Production MT/yr	Physical State	Percent Solids	Bulk Density MT/m^3	Dry	Wet	Dry	Wet
Cold Rolling Mill - Waste Pickle Liquor - Hydrochloric Acid (HCl)	8B	700,000	Liquid	20	1.1	3,200	37,500	-	34,000
Galvanizing Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	9A	125,000	Sludge	30	1.6	1,400	4,500	-	2,800
(HCl)	9B	125,000	Sludge	30	1.1	300	1,000	-	900
Ferrosilicon Manufacture - Miscellaneous Dusts	11	40,000	Dust	-	1.5	13,500	-	9,000	-
Ferrochrome Manufacture - Slag	12A	35,000	Slag	-	1.7	61,300	-	36,000	-
Ferrochrome Manufacture - Dust	12B	35,000	Dust	-	1.5	5,300	-	3,500	-
Ferrochrome Manufacture - Sludge	12C	35,000	Sludge	40	1.2	5,300	13,200	-	11,000
Silicomanganese Manufacture - Slag and Scrubber Sludge	13	40,000	Slag	-	1.7	44,000	-	25,900	-
Ferromanganese Manufacture - Slag and Sludge	14	30,000	Sludge	40	1.4	8,900	22,200	-	15,900
Copper Smelting - Acid Plant Blowdown Sludge	15	100,000	Sludge	40	1.2	300	700	-	600

Table 5 (Cont.) Summary Table of Waste Quantities, Production Values and Gross Physical Characteristics

Waste Stream	No.	Typical Plant Production MT/yr	Physical State	Percent Solids	Bulk Density MT/m^3	Quantity Generated From Typical Plant			
						Weight MT/yr		Volume m^3/yr	
						Dry	Wet	Dry	Wet
Electrolytic Copper Refining-Mixed Sludge	16	160,000	Sludge	40	1.3	400	1,100	-	700
Lead Smelting - Sludge	17	110,000	Sludge	30	1.2	6,500	21,600	-	18,000
Electrolytic Zinc Manufacture Sludge	18	100,000	Sludge	30	1.3	2,600	8,700	-	6,700
Pyrometallurgical Zinc Manufacture - Sludges	19A	107,000	Sludge	30	1.3	13,000	43,000	-	33,100
Pyro. Zinc Mfg. - Retort Gas Scrubber Bleed	19B	107,000	Sludge	30	1.8	1,100	2,200	-	1,200
Aluminum Manufacture - Scrubber Sludges	20	153,000	Sludge	30	1.4	17,900	59,500	-	41,400
Aluminum Manufacture - Spent Potliners and Skimmings	21	153,000	Solid	-	2.4	9,000	-	3,700	-
Aluminum Manufacture - Shot Blast and Cast House Dusts	22	153,000	Dusts	-	1.2	1,100	-	1,000	-
Pyrometallurgical Antimony Manufacture - Blast Furnace Slag	23	2,700	Slag	-	2.0	7,700	-	3,800	-
Electrolytic Antimony Manufacture - Spent Anolyte Sludge	24	900	Sludge	30	1.4	200	600	-	450

Table 5 (Cont.) Summary Table of Waste Quantities, Production Values and Gross Physical Characteristics

Waste Stream	No.	Typical Plant Production MT/yr	Physical State	Percent Solids	Bulk Density MT/m^3	Quantity Generated From Typical Plant: Weight MT/yr Dry	Weight MT/yr Wet	Volume m^3/yr Dry	Volume m^3/yr Wet
Titanium Manufacture - Chlorinator Condenser Sludge	25	7,600	Sludge	40	1.2	2,500	6,300	-	5,200
Copper Refining - Blast Furnace Slag	27	10,000	Slag	-	2.0	3,500	-	1,800	-
Lead Refining - SO_2 Scrubwater Sludge	28	10,000	Sludge	30	1.2	450	1,500	-	1,250
Aluminum Refining - Scrubber Sludge	29	20,000	Sludge	30	1.2	1,500	5,000	-	2,500
Aluminum Refining - High Salt Slag	30	10,000	Slag	-	2.0	14,000	-	7,000	-

PART I

ALTERNATIVE TREATMENT OF HAZARDOUS WASTES FROM THE METALS SMELTING AND REFINING INDUSTRIES

NOTE:

The costs, cost factors, and methods used to calculate capital and annual costs are presented in Appendix A, "Cost Data Base."

SECTION I

FERROUS METAL SMELTING AND REFINING HAZARDOUS WASTES

A. Iron and Steel Coke Production

1. Ammonia Still Lime Sludge
(Waste Stream Number 1)

Waste Description. Ammonia is removed from coke oven gas by spray cooling and scrubbing and then sold as ammonium sulfate or anhydrous ammonia. Concentration of the liquor is achieved in an ammonia still which produces a waste lime sludge formed as a result of adding milk of lime to decompose ammonium salts. Ammonia still lime sludge is generated at the rate of 676 MT/yr (dry weight) for a typical plant producing 2,500,000 MT of steel per year.

Pertinent analyses of the sludge is as follows:

Ammonia Still Lime Sludge Analyses (ppm)[1]

Chromium	55	Lead	36
Copper	27	Zinc	673
Manganese	550	Cyanide	12
Nickel	10	Phenol	6.6
		Oil & Grease	31,250

Analyses of the filtrate from solubility tests on ammonia still sludge yielded 20 mg/l phenol, 198 mg/l cyanide and pH 11.5. The solubility tests indicate that significant concentrations of cyanide and phenol can leach into ground or surface waters. This waste may therefore be considered potentially hazardous.[1]

Present Method for Waste Disposal. These sludges are normally disposed in open dumps and may pose potential hazards to the environment if the cyanides and phenols reach ground or surface waters. Heavy metals precipitated in the sludge as hydroxides if acidified may also reach surface or ground waters posing additional threats to the environment.

Recommended Alternative Treatment Method. Disposal of ammonia still lime sludge in a secure chemical landfill is an environmentally sound procedure. This is the preferred method of disposal for several very valid reasons. The lime content is utilized to detoxify the hazardous constituents, such as the heavy metals which are maintained as insoluble hydroxides. The sludge is containerized for chemical landfilling.

Cost of Alternative Method of Waste Handling. A schematic diagram of the flow scheme for the alternative method of disposal is shown in Figure 1. A summary of capital and operating costs is shown in Table 6.

Treatment consists of sludge storage in an existing 7.6 m^3 (2,000 gal.) tank from which the sludge is containerized and disposed in a chemical landfill.

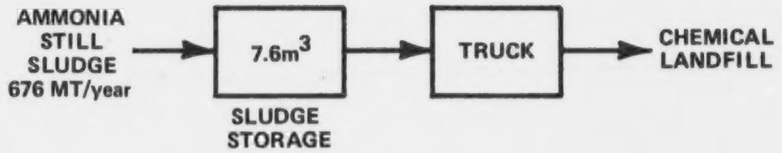

AMMONIA STILL SLUDGE 676 MT/year
7.6m3
SLUDGE STORAGE
TRUCK
CHEMICAL LANDFILL

Figure 1. SCHEMATIC DIAGRAM OF AMMONIA STILL SLUDGE ALTERNATIVE TREATMENT (WASTE STREAM NUMBER 1)

TABLE 6

Capital and Annual Operating Costs for Ammonia Still Lime Sludge - Alternative Treatment Method (Waste Stream Number 1)

ANNUAL PRODUCTION (METRIC TONS): 2,500,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 700 **WET WEIGHT** 2,300

CAPITAL COST

FACILITIES

EQUIPMENT

Transportation equipment costs are included in land disposal costs.

CONTINGENCY	
TOTAL CAPITAL INVESTMENT	
ANNUAL COST	
AMORTIZATION	
OPERATIONS AND MAINTENANCE (O&M)	
OPERATING PERSONNEL	
EQUIPMENT REPAIR AND MAINTENANCE	
MATERIALS	
WASTE DISPOSAL	$181,450
TAXES AND INSURANCE	
ENERGY	
TOTAL ANNUAL COST	$181,450
RECOVERY VALUE	
NET ANNUAL COST	

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS	-	$78.89
DRY BASIS	-	259.21
COST/METRIC TON OF PRODUCT	-	0.07

SHORT TONS = 0.9 x METRIC TON

A. Iron and Steel Coke Production

2. Decanter Tank Tar
(Waste Stream Number 2)

Waste Description. Coke oven gases are cooled with water sprays which condense tars. The condensed tars are sent to a separation or decanter tank where dense materials settle to the bottom and are removed as decanter tank tars. The lighter, less dense materials such as oils are decanted for by-product recovery. A typical steel mill producing 2,500,000 MT/yr will generate 5,524 MT/yr of decanter tank tar.

These tars contain high concentrations of phenol, cyanide and heavy metals and are therefore, considered potentially hazardous. Tar analyses and solubility test filtrate analyses are as follows:

Analysis of Tar (ppm)[1]

Oil and Grease	15-30%	Nickel	< 10
Phenol	0.2%	Lead	30
Chromium	4	Zinc	20
Copper	1	Cyanide	6
Manganese	44	Water	70-85%
Thermal Content	2,700-5,400 Btu's/lb		

Solubility Test Filtrate Analyses (mg/l)[1]

Manganese	< 0.01	Phenol	Approx. 500
Chromium	< 0.01	Cyanide	0.59
Copper	< 0.03	Oil and Grease	198
Lead	< 0.2	pH	8.9
Nickel	< 0.05		
Zinc	< 0.01		

Present Waste Disposal Methods. Some steel mills sell these tars as pitch for asphaltic types of use or dispose them in open dumps. These practices are environmentally inadequate because the toxic constituents can leach into ground or to surface waters.

Recommended Alternative Treatment Method. The recommended alternative treatment method is containerization and chemical landfill disposal. This manner of disposal would prevent the phenols, cyanides and oil and grease from entering the environment.

Cost for Alternative Method of Waste Handling. A schematic diagram of the alternative waste handling process is shown in Figure 2. A summary of capital and operating costs is shown in Table 7 .

The waste tars are stored in an existing 19 m^3 (5,000 gal.) holding tank for containerization and disposal in a chemical or secure landfill.

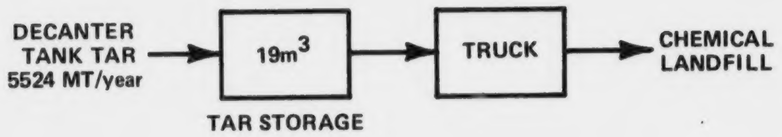

DECANTER
TANK TAR
5524 MT/year
19m3
TAR STORAGE
TRUCK
CHEMICAL
LANDFILL

Figure 2. SCHEMATIC DIAGRAM OF DECANTER TANK TAR ALTERNATIVE TREATMENT (WASTE STREAM NUMBER 2)

TABLE 7

Capital and Annual Operating Costs For Decanter Tank Tar - Alternative Treatment (Waste Stream Number 2)

ANNUAL PRODUCTION (METRIC TONS): 2,500,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 5,500 **WET WEIGHT** 27,600

CAPITAL COST	
FACILITIES	
EQUIPMENT	
Transportation equipment costs are included in land disposal costs.	
CONTINGENCY	
TOTAL CAPITAL INVESTMENT	
ANNUAL COST	
AMORTIZATION	
OPERATIONS AND MAINTENANCE (O&M)	
OPERATING PERSONNEL	
EQUIPMENT REPAIR AND MAINTENANCE	
MATERIALS	
WASTE DISPOSAL	$1,782,410
TAXES AND INSURANCE	
ENERGY	
TOTAL ANNUAL COST	$1,782,410
RECOVERY VALUE	
NET ANNUAL COST	

COST/METRIC TON OF WASTE	NET	TOTAL
WET BASIS	-	$ 64.58
DRY BASIS	-	324.09
COST/METRIC TON OF PRODUCT	-	0.71

SHORT TONS = 0.9 x METRIC TON

B. Iron and Steel Production

1. Basic Oxygen Furnace - Wet Emission Control Unit Sludge
   (Waste Stream Number 3)

2. Open Hearth Furnace - Emission Control Dust
   (Waste Stream Number 4)

3. Electric Furnace - Wet Emission Control Sludge
   (Waste Stream Number 5)

Waste Description. The sludges and dusts are generated in wet and/or dry air cleaning systems, and may contain significant quantities of leachable fluorides, lead, zinc and possibly copper and chromium as well. The latter two heavy metals occur primarily in electric furnace wet emission control sludge. The iron content of these dusts and sludges is very high and varies from 29 to 55% of the total weight. Analyses and solubility test data which indicate the potentially hazardous nature of these wastes are summarized as follows:

Analyses of Dry Emission
Control Particulates[1]

		Basic Oxygen Furnace Emission Control Sludge	Open Hearth Furnace Emission Control Dust	Electric Furnace Emission Control Sludge
Iron	%	54	55	29
Zinc	%	3	5	16
Manganese	%	1	0.5	4
Lead	%	0.4	0.8	2
Cyanide	ppm	500	-	-
Chromium	ppm	120	600	1,300
Copper	ppm	210	1,000	2,700
Nickel	ppm	65	240	300
Fluorine	ppm	-	-	2,400

Analyses of Filtrate from Solubility Tests on Emission Control Particulates[1] (mg/l)

	Basic Oxygen Furnace Emission Control Sludge	Open Hearth Furnace Emission Control Dust	Electric Furnace Emission Control Sludge
Manganese	0.5	12	0.03
Chromium	0.09	0.03	94
Copper	0.09	0.06	0.17
Lead	< 0.2	0.4	2.0
Nickel	< 0.5	0.4	< 0.05
Zinc	0.13	0.1	0.06
Fluorine	14	19	11
pH	10.4	8.9	11.5

Total amounts of waste generated from typical mills are summarized as shown following:

	Basic Oxygen Furnace Emission Control Sludge	Open Hearth Furnace Emission Control Sludge	Electric Furnace Emission Control Sludge
Typical Plant Production (MT Steel/yr)	2.0×10^6	0.5×10^6	0.5×10^6
Emission Control Particulate Generation (kg/MT steel)	17.3	13.7	8.7
Total Generation (MT/year)	34,600	6,850	4,350

Present Waste Disposal Methods. When these wastes are sufficiently low in lead and zinc, they are recycled to the sintering plant. When the contaminant concentrations are too high and cannot be diluted with other low lead and zinc waste materials such as rolling mill sludge, they are disposed in open dumps. Surface or groundwater may leach toxic elements from these waste materials into the environment.

Recommended Alternative Treatment Method. The proposed alternative treatment process is one that removes the lead and zinc contaminants from the high iron content waste materials, in a central recovery facility. The lead and zinc recovered as oxides may be sold to lead and zinc smelters. The residue, high in iron oxide, is then recycled to the blast furnace.

The alternative treatment is known as the Kawasaki Process and was developed by Kawasaki Steel Corporation (Japan). Figure 3 presents a schematic flow diagram of the process. The process recovers most of the lead and 95% of the zinc content of the feed in dust form and produces prereduced pellets that can be fed to the blast furnace.

Iron oxide fines from emission control particulates are dewatered if necessary and analyzed. They are mixed and the water and carbon content is adjusted. The mixture is pelletized on disc pelletizers without addition of any bentonite, as BOF dust is claimed to have a good binding effect. The green pellets are charged onto the grate preheater. The hematite bonded pellets enter the kiln where coke serves as a fuel and to generate a reducing atmosphere. Lead and zinc are precipitated from the kiln's off-gases and sent to zinc smelters. The prereduced pellets pass through a rotating cooler prior to being discharged. The amount of zinc acceptable in the charge is limited to roughly 5%.

The process was developed in the mid sixties. The first commercial plant was put onstream at the Kawasaki Chiba Works in December 1968. A 240,000 tons per year plant was commissioned for the Kawasaki Mizushima Works in 1973. As of today, this is the most advanced and commercially proven process for zinc containing dusts to produce zinc-free prereduced iron pellets for recycle to the blast furnace.

Cost of Alternative Treatment Method. Each steel mill combines the open hearth dust or electric furnace sludge with the BOF sludge. This sludge is then centrifuged. Approximately 50,000 metric tons (55,000 s. tons) of centrifuge discharge (dry weight) is produced annually. Eight man-hours per day are assigned to the operation. Costs are shown in Table 8 .

The centrifuge discharge is shipped to a centrally located processing plant sized to accept wastes from eight or nine mills. The waste is combined with coke breeze, pelletized and processed in a Kawasaki kiln.

Costs for a central Kawasaki process facility serving eight mills are presented in Table 9 . The costs shown are developed from cost estimates.

About 70,000 metric tons (77,000 s. tons) of coke breeze are required each year. Fuel for the drier operation totals 138 x 10^9 kg cal (248 x 10^9 Btu's) per year; average electrical energy consumption is equivalent to 1,000 hp. It is assumed that each of the mills generates 70,000 metric tons (77,000 s. tons) of centrifuge discharge (wet weight) which is transported 40 km (25 miles) to

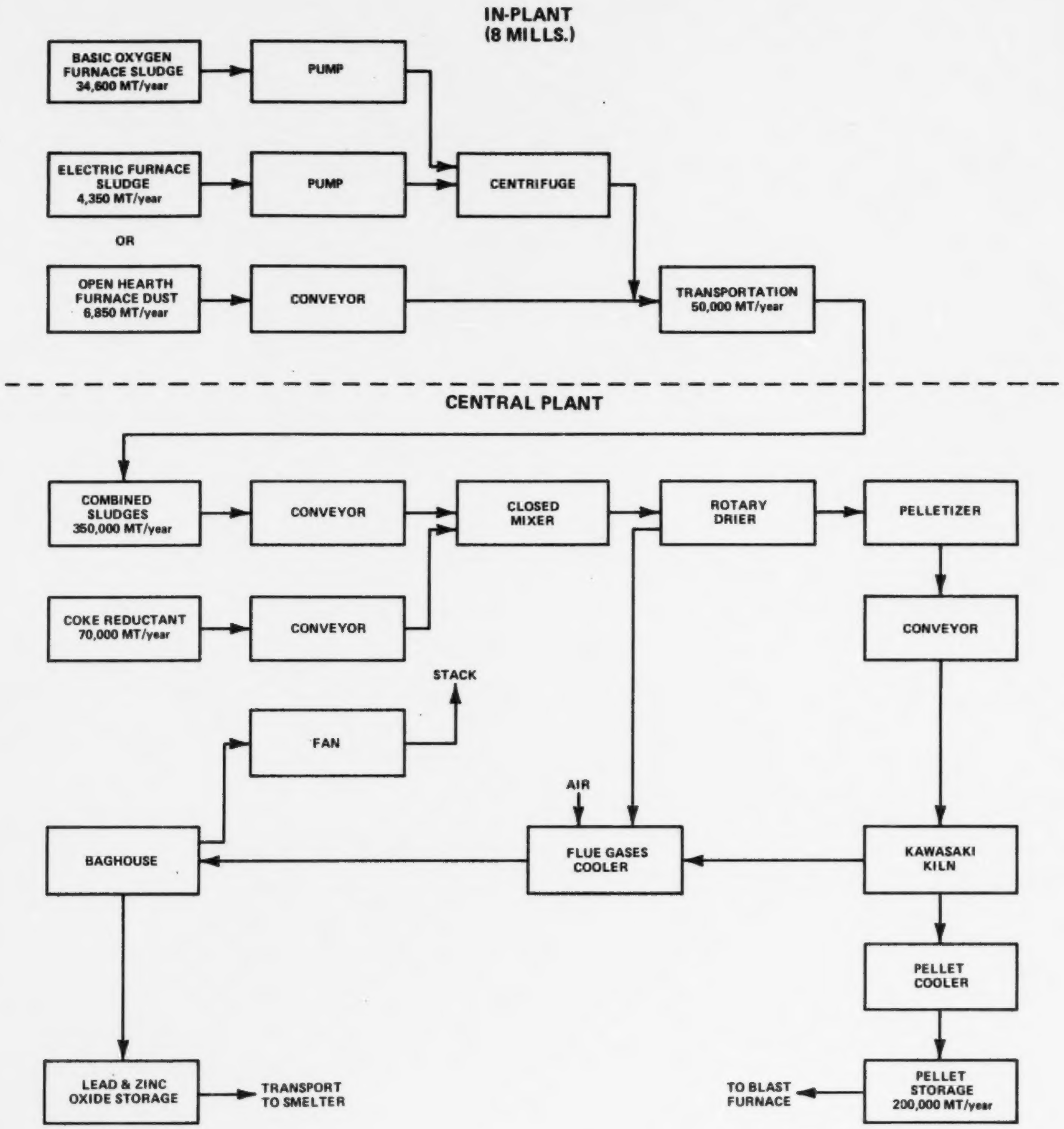

IN-PLANT
(8 MILLS.)
BASIC OXYGEN FURNACE SLUDGE 34,600 MT/year
PUMP
ELECTRIC FURNACE SLUDGE 4,350 MT/year
PUMP
CENTRIFUGE
OR
OPEN HEARTH FURNACE DUST 6,850 MT/year
CONVEYOR
TRANSPORTATION 50,000 MT/year
CENTRAL PLANT
COMBINED SLUDGES 350,000 MT/year
CONVEYOR
CLOSED MIXER
ROTARY DRIER
PELLETIZER
COKE REDUCTANT 70,000 MT/year
CONVEYOR
CONVEYOR
STACK
FAN
AIR
BAGHOUSE
FLUE GASES COOLER
KAWASAKI KILN
PELLET COOLER
LEAD & ZINC OXIDE STORAGE
TRANSPORT TO SMELTER
TO BLAST FURNACE
PELLET STORAGE 200,000 MT/year

Figure 3. SCHEMATIC DIAGRAM OF ALTERNATIVE PROCESS FOR MATERIAL RECOVERY FROM STEEL MILL EMISSION CONTROL WASTES (WASTE STREAMS 3, 4 AND 5)

TABLE 8

In-Plant Capital and Annual Operating Costs for Each of Eight Mills Using a Central Processing Facility (Waste Streams Numbers 3, 4, and 5)

ANNUAL PRODUCTION (METRIC TONS): 2,500,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 40,000 **WET WEIGHT** 94,500

CAPITAL COST		
FACILITIES		
Sludge Sump		$ 6,600
EQUIPMENT		
Centrifuge	$28,000	
Sludge Conveyor	20,000	
Pump	1,700	
Piping	4,900	
Installation	42,700	97,300
CONTINGENCY		20,800
TOTAL CAPITAL INVESTMENT		$124,700
ANNUAL COST		
AMORTIZATION		20,300
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$47,250	
EQUIPMENT REPAIR AND MAINTENANCE	4,990	
MATERIALS		
WASTE DISPOSAL		
TAXES AND INSURANCE	4,990	57,230
ENERGY		6,120
TOTAL ANNUAL COST		$ 83,680
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS	--	$0.89
DRY BASIS	--	2.09
COST/METRIC TON OF PRODUCT	--	0.03

SHORT TONS = 0.9 x METRIC TON

TABLE 9

Capital and Annual Operating Costs for Central Treatment Facility (Kawasaki Process) Serving Eight Mills (Waste Streams Numbers 3, 4, and 5)

ANNUAL PRODUCTION (METRIC TONS): 20,000,000 (~8 plants)

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 350,000 **WET WEIGHT** 500,000

CAPITAL COST		
FACILITIES		$5,930,000
EQUIPMENT		
Installed Equipment		5,930,000
CONTINGENCY		2,372,000
TOTAL CAPITAL INVESTMENT		$14,232,000
ANNUAL COST		
AMORTIZATION		$ 2,319,820
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$ 453,600	
EQUIPMENT REPAIR AND MAINTENANCE	569,000	
MATERIALS	3,500,000	
WASTE DISPOSAL *	735,000	
TAXES AND INSURANCE	569,280	5,827,160
ENERGY		751,200
TOTAL ANNUAL COST		$ 8,898,180
RECOVERY VALUE		$ 4,000,000
NET ANNUAL COST		4,898,180

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS	$9.80	$17.80
DRY BASIS	13.99	25.42
COST/METRIC TON OF PRODUCT	0.24	0.44

*Waste Transport

SHORT TONS = 0.9 x METRIC TON

the central processing plant at a cost of $0.06/ton mile. Four men per shift are estimated to be required for operating the process facility.

The major product generated in the process is iron pellets. About 200,000 metric tons (220,000 s. tons) of iron pellets are recovered annually. A value of $20 per metric ton ($18 s. ton), the approximate price of iron pellets, is assigned to the material. No value was assigned for the recovered lead and zinc oxides.

Assuming eight mills share the costs of the centralized processing plant, each mill has the following individual costs:

Capital Cost	
In-plant	$ 124,700
Process Plant (Pro-rated share)	1,779,000
TOTAL	$1,903,700
Annual Cost	
In-plant	$ 83,680
Process Plant (Pro-rated share)	1,112,270
TOTAL	$1,195,950
Recovered Material Value	$ 500,000
Net Annual Cost	$ 695,950

Cost/Metric Ton of Waste	Net	Total
Wet Basis	$ 7.36	$12.66
Dry Basis	17.40	29.90
Cost/Metric Ton of Product	0.28	0.48

B. Iron and Steel Production

4. Rolling Mill Sludge
(Waste Stream Number 6)

Waste Description. In the production of finished steel, the rough billets, blooms and slabs from continuous casting mills and primary rolling mills are sent to hot rolling mills where they are converted into a wide variety of finished or semi-finished products including bars, rods, tubes, rails, and plates. These hot rolling operations produce scale which is collected in pits. The coarse scale is removed from the pits and recycled to the sinter plant to reclaim iron value. The finer materials settling to the bottom of the pit constitute the hot rolling mill sludge. The typical large integrated steel plant processing 1,800,000 MT of steel through the hot rolling mill per year produces 3,130 MT/yr of hot rolling mill sludge solids. The sludge solids generation rate is 1.74 kg/MT of rolled steel.[1]

The principal component of mill scale is iron and iron oxide which comprise 85-95% of the dry weight. Oil and grease content of the scale ranges from 5-15% dry weight. The estimated trace metal composition of the hot rolling mill sludge solids is shown as follows:[1]

Analysis of Solids in Sludge[1] (%)

Chromium	0.03	Nickel	0.025
Copper	0.025	Lead	0.05
Manganese	0.35	Zinc	0.004
Oil-Grease	5-16		

The oil and grease and perhaps trace metal content of this sludge could present an environmental problem if leached into ground or surface waters. An indication of the low magnitude of this possibility is shown by the following data:

Solubility Test Filtrate Analyses (mg/l)[1]

Manganese	< 0.01	Nickel	< 0.05
Chromium	0.05	Zinc	0.03
Copper	0.03	Oil & Grease	0.5
Lead	< 0.2	pH	9.6

Present Waste Disposal Methods. At the present time, sludges removed from hot rolling mills are open dumped on land. This practice could produce ground or surface water contamination from contained oil and grease and possibly from heavy metals.

Recommended Alternative Method for Waste Treatment. Because of the very high iron and iron oxide content of hot rolling mill sludge solids (85-95%), it should be possible to recycle these solids to the sinter plant for agglomeration and reclamation of iron values. A system for processing and reclamation of this sludge is shown in Figure 4. In this system, the scale pit sludge amounting to 14 m^3/day at 40% solids is centrifuged to a solids concentration of 80%. These solids, amounting to 11 MT per day would be sent to the sinter plant and processed for iron recovery. The filtrate from the centrifuge amounting to 14 m^3 would be sent to the mill wastewater treatment plant where it would comprise less than 1% of total plant wastewater flow.

The above system will eliminate land disposal of hot rolling mill sludge and thus obviate any associated ground or surface water pollution potential. The oil and grease content of the sludge solids which are recycled to the sinter may result in increased hydrocarbon emissions from the sinter operation. All of the iron values are recovered.

Alternative Waste Treatment Costs. The underflow from the existing scale pit is pumped to a 25 hp centrifuge. The centrifuge is operated 8 hours per day. The centrifuge discharge is put in receiving bins and transported to a sinter plant for recycling. The transport charge is estimated at $1/metric ton ($0.90/s. ton). Four man-hours of labor per day are assigned to the operation, excluding transport.

The centrifuge discharge is estimated to contain 1,953 metric tons (2,148 s. tons) of iron on an annual basis. A recovery value of $20 per metric ton ($18/s. ton) is assigned to this waste. This value is based on the approximate value of iron pellets.

A block diagram of the recycle process is shown in Figure 4 and the cost development for the process is summarized in Table 10.

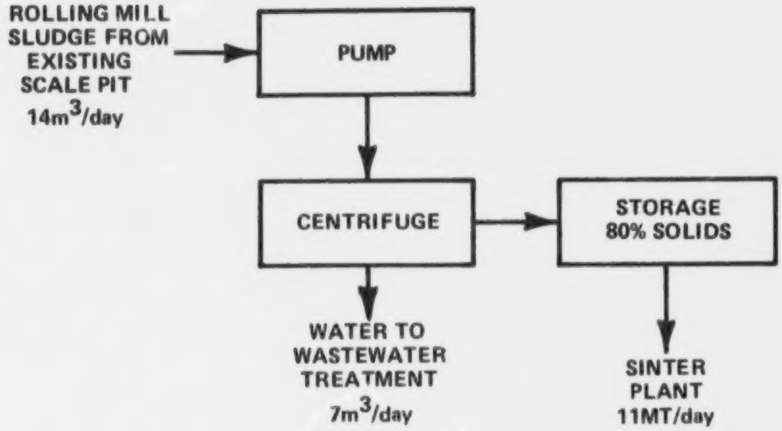

ROLLING MILL SLUDGE FROM EXISTING SCALE PIT
14m3/day
PUMP
CENTRIFUGE
STORAGE 80% SOLIDS
WATER TO WASTEWATER TREATMENT
7m3/day
SINTER PLANT
11MT/day

Figure 4. SCHEMATIC DIAGRAM OF ROLLING MILL SLUDGE ALTERNATIVE TREATMENT. (WASTE STREAM NUMBER 6)

TABLE 10

Capital and Annual Operating Costs for Rolling Mill Sludge - Alternative Treatment (Waste Stream Number 6)

ANNUAL PRODUCTION (METRIC TONS): 1,800,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 3,100 **WET WEIGHT** 7,800

CAPITAL COST		
FACILITIES		
Sump		$ 3,100
EQUIPMENT		
Centrifuge	$45,000	
Sludge Bin	2,700	
Pump	1,000	
Piping	400	
Installation	34,800	83,900
CONTINGENCY		17,400
TOTAL CAPITAL INVESTMENT		$ 104,400
ANNUAL COST		
AMORTIZATION		$ 17,020
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$18,900	
EQUIPMENT REPAIR AND MAINTENANCE	4,180	
MATERIALS		
WASTE DISPOSAL	3,920	
TAXES AND INSURANCE	4,180	31,180
ENERGY		2,170
TOTAL ANNUAL COST		$ 50,370
RECOVERY VALUE		39,060
NET ANNUAL COST		$ 11,310

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS	$1.45	$6.46
DRY BASIS	3.65	16.25
COST/METRIC TON OF PRODUCT	0.006	0.03

SHORT TONS = 0.9 x METRIC TON

B. Iron and Steel Production

5. Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (Waste Stream Number 7A and 7B)

Waste Description. In cold rolling mills, previously hot rolled steel is further processed to improve surface qualities and workability. Before further treatment in the cold rolling mill, the steel products are dipped in vats of hydrochloric or sulfuric acid (i.e. pickle liquor) to clean surfaces. After removal from the pickling vats, the steel forms (bars, plates, etc.) are rinsed with water. The rinsewater is neutralized with lime resulting in lime sludge. When sulfuric acid is used for pickling, the sludge solids generation rate is 0.16 kg/MT of steel. When hydrochloric acid is used, the sludge solids generation rate is 0.04 kg/MT steel. A typical plant which processes 700,000 MT of steel annually in the cold rolling mill will produce 112 MT of dry sludge solids (373 MT wet) if sulfuric acid is used for pickling or 28 MT of dry solids (93 MT wet) if hydrochloric acid is used. Cold rolling mill sludges will be composed principally of calcium sulfate, iron, iron sulfate, iron chloride, and iron oxides. They will also contain oil and grease and hydroxides of heavy metals including chromium, nickel, copper, and zinc. They are considered potentially hazardous because toxic heavy metals and oil and grease may solubilize and enter the environment.

A sample sludge analysis is as follows:

Sample Acid Rinsewater Sludge Analysis (ppm)[1]

Chromium	1,612	Zinc	815
Copper	403	Cyanide	9.4
Manganese	658	Oil and Grease	35,900
Nickel	2,035	Phenol	1.8
Lead	191		

Present Waste Disposal Methods. At the present time, sludges from the cold rolling mill are open dumped on land. This practice could pose a potential threat to groundwater and surface water quality if oil and grease and solubilized metals in leachate either percolate through permeable soils to groundwater or are carried in runoff to surface waters.

Recommended Alternative Treatment Method. The disposal of acid rinse neutralization sludges on land may be readily eliminated by combining them with spent pickle liquor for recovery of iron and acid. The volume of clarifier underflow sludges from neutralization of acid rinsewater will be less than one cubic meter/day. This volume is insignificant compared to the daily volume of spent pickle liquor amounting to 200 m^3/day. The next section of this report on waste stream number 8, describes processes for iron and acid recovery from spent pickle liquor. The elimination of land disposal of acid rinse neutralization sludges obviates any chance of ground or surface water contamination from their disposal.

There are no known plants now using the proposed method of handling acid rinse neutralization sludges.

Costs for Alternative Treatment Method of Waste. A diagram showing the recycle of acid rinsewater neutralization sludge is shown in Figure 5. The costs for the alternative disposal of sulfuric and hydrochloric acid rinsewater neutralization sludge are summarized in Tables 11 and 12 .

The sludge is pumped periodically to a storage tank where it is mixed with spent pickle liquor. Either two or three man-hours per week are assigned to the operation, depending on volume of acid neutralized sludge. The sludge has no recovery value because of its relatively low volume but will add to overall recovery of iron from spent pickle liquors.

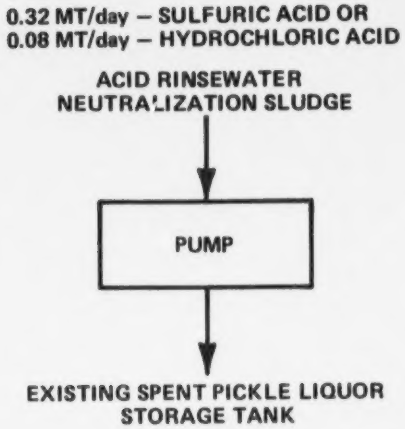

0.32 MT/day – SULFURIC ACID OR
0.08 MT/day – HYDROCHLORIC ACID
ACID RINSEWATER
NEUTRALIZATION SLUDGE
PUMP
EXISTING SPENT PICKLE LIQUOR
STORAGE TANK

Figure 5. SCHEMATIC DIAGRAM OF ACID RINSEWATER NEUTRALIZATION SLUDGE RECYCLE. (WASTE STREAM NUMBER 7A & B)

TABLE 11

Capital and Annual Operating Costs for Alternative Treatment of Sulfuric Acid Rinse Water Neutralization Sludge (Waste Stream Number 7A)

ANNUAL PRODUCTION (METRIC TONS): 700,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 100 **WET WEIGHT** 400

CAPITAL COST		
FACILITIES		
EQUIPMENT		
Pump	$800	
Piping	600	
Installation	800	$2,200
CONTINGENCY		400
TOTAL CAPITAL INVESTMENT		$ 2,600
ANNUAL COST		
AMORTIZATION		$ 420
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$2,110	
EQUIPMENT REPAIR AND MAINTENANCE	100	
MATERIALS		
WASTE DISPOSAL		
TAXES AND INSURANCE	100	2,310
ENERGY		10
TOTAL ANNUAL COST		$2,740
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS		$ 6.85
DRY BASIS		27.40
COST/METRIC TON OF PRODUCT		0.004

SHORT TONS = 0.9 x METRIC TON

TABLE 12.

Capital and Annual Operating Costs for Alternative Treatment of Hydrochloric Acid Rinse Water Neutralization Sludge (Waste Stream Number 7B)

ANNUAL PRODUCTION (METRIC TONS): 700,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 30 **WET WEIGHT** 300

CAPITAL COST		
FACILITIES		
EQUIPMENT		
Pump	$800	
Piping	600	
Installation	800	$2,200
CONTINGENCY		400
TOTAL CAPITAL INVESTMENT		$2,600
ANNUAL COST		
AMORTIZATION		
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$1,400	
EQUIPMENT REPAIR AND MAINTENANCE	100	
MATERIALS		
WASTE DISPOSAL		
TAXES AND INSURANCE	100	$1,600
ENERGY		10
TOTAL ANNUAL COST		$2,030
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS		$ 6.77
DRY BASIS		67.67
COST/METRIC TON OF PRODUCT		0.003

SHORT TONS = 0.9 x METRIC TON

B. Iron and Steel Production

6. Cold Rolling Mill - Waste Pickle Liquor

a. Sulfuric Acid
(Waste Stream Number 8A)

Waste Description. Iron oxides, oil, grease and dirt must be removed from metal surfaces before subsequent steel finishing operations such as cold rolling, annealing, galvanizing and tin plating. This is often done by dipping the metal in 20% sulfuric acid followed by water rinsing to remove the acid (hydrochloric acid is also used for pickling).

The quantity of waste acid generated from a typical plant which pickles 700,000 MT of steel per year is 79,000 MT. The generation rate of waste sulfuric acid pickle liquor is 113 kg/MT of steel processed.

Waste sulfuric acid pickle liquor contains 13-15% iron principally as iron sulfate from the reaction of sulfuric acid on iron oxide scale. In addition, dissolved or particulate trace metals, including chromium, copper, nickel, lead, zinc, oil, and grease will be present. The highly acid nature of pickle liquor, toxic heavy metals, oil and grease make this waste a potential environmental hazard. A sample analysis is as follows:

Sample Analysis of Waste
Sulfuric Acid Pickle Liquor[1] (mg/l)

Ferrous Sulfate	13-15%
Free Sulfuric Acid	2-7%
Chromium	13
Copper	10
Manganese	230
Nickel	14
Lead	2.2
Zinc	12

Present Waste Disposal Methods. At the present time, waste sulfuric acid pickle liquor is generally handled by contract disposal service companies who neutralize it and leave residual solids in sludge lagoons. These solids will be primarily calcium sulfate, iron sulfates, and heavy metals. Impoundment in unlined lagoons with permeable soils could create groundwater pollution problems if sulfite or other reduced forms of sulfur or toxic heavy metals percolate to groundwater. Hence, these wastes are potentially hazardous.

Recommended Alternative Treatment Method. Figure 6 presents a system for recovery of iron from spent sulfuric acid pickling liquor as ferric chloride. The typical steel plant which pickles 2,000 MT/day of steel produces 190 m^3 of spent sulfuric acid pickle liquor. By the use of the conceptual system shown, an estimated 63 MT of ferric chloride can be recovered per day. This ferric chloride can find use in municipal wastewater treatment as a primary coagulant and for phosphorus removal.

In the system, 190 m^3/day of spent sulfuric acid pickle liquor is first blended with 77 m^3 of 40% calcium chloride solution. The resulting slurry is centrifuged for solids concentration. Approximately 36 m^3 of gypsum (i.e. $CaSO_4$) cake weighing 67 MT is produced per day. This cake would be disposed in a chemical landfill.

The filtrate from the centrifuge amounting to 240 m^3/day is sent to reduction tanks where scrap iron is added to increase conversion of iron to ferrous chloride to deplete hydrochloric acid in the filtrate. The reduced filtrate is then sent to chlorinators where ferrous chloride ($FeCl_2$) is converted to ferric chloride solution ($FeCl_3$). Evaporators are then used to concentrate the ferric chloride to 110 m^3 of 42-45% $FeCl_3$ per day which would be marketed. Evaporated water amounting to 127 m^3/day can be recycled for process use where high quality water is needed.

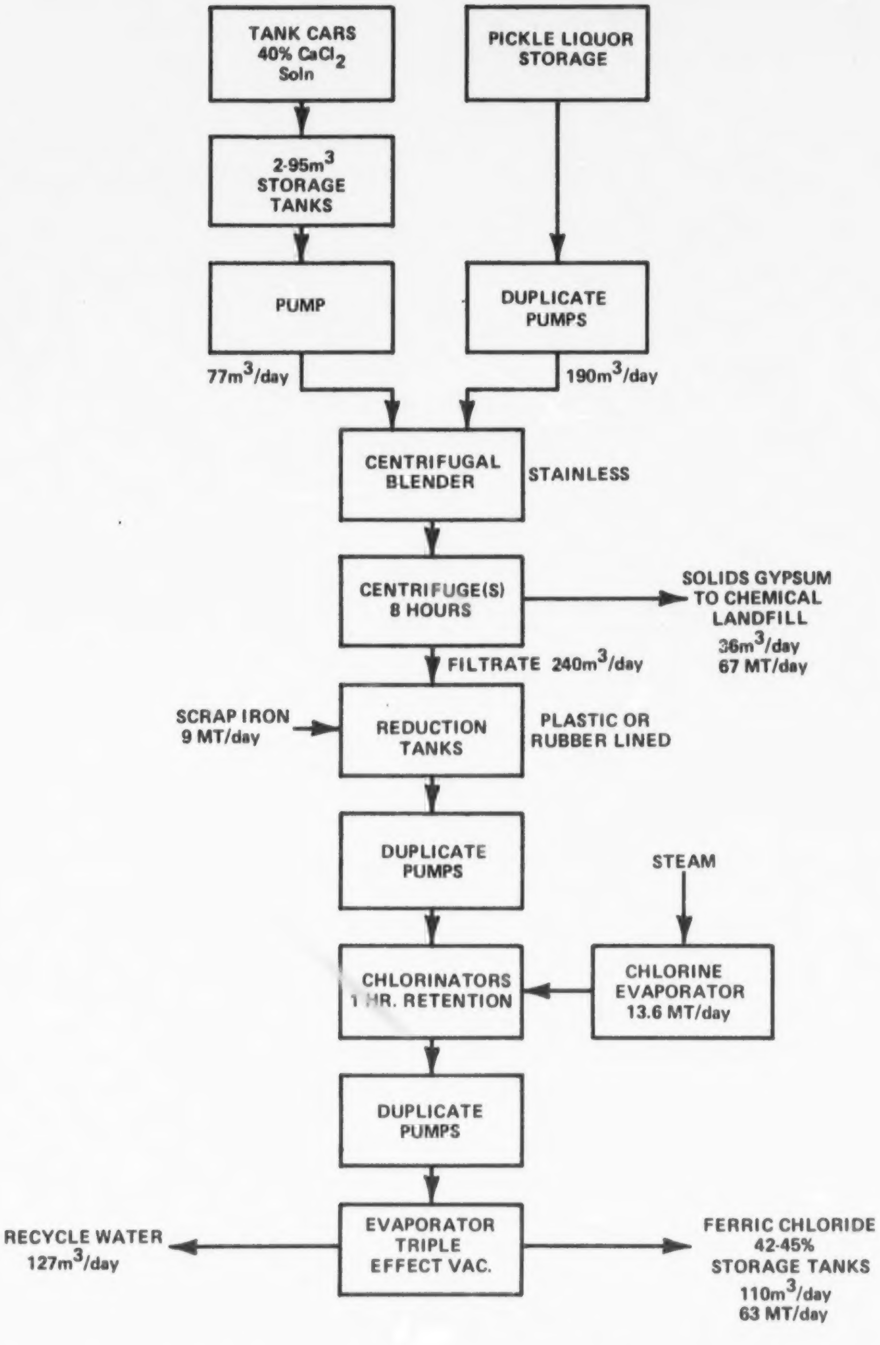
The environmental advantages associated with the ferric chloride recovery process include substantial reduction of waste volume for disposal (190 m^3 reduced to 30 m^3) as well as resource recovery. An effluent discharge from neutralization of pickle liquor would be eliminated since a portion is recovered as evaporator condensate and a portion is recycled as the 42-45% $FeCl_3$ product.

The gypsum cake residue containing the potentially hazardous constituents, amounting to 67 MT/day, is disposed in an environmentally sound chemical landfill.

The above system is conceptual and is not being used by the industry.

Costs for Alternative Treatment Process. A schematic diagram of the alternative recovery process for waste sulfuric acid pickle liquor is shown in Figure 6. The costs for the process are described and summarized in Table 13 .

The pickle liquor is mixed with calcium chloride in a centrifugal blender and centrifuged. The centrifuge discharge is chemically landfilled. About 67 metric tons (74 s. tons) are disposed daily.



TANK CARS 40% CaCl2 Soln
PICKLE LIQUOR STORAGE
2·95m3 STORAGE TANKS
PUMP
DUPLICATE PUMPS
77m3/day
190m3/day
CENTRIFUGAL BLENDER
STAINLESS
CENTRIFUGE(S) 8 HOURS
SOLIDS GYPSUM TO CHEMICAL LANDFILL
36m3/day
67 MT/day
FILTRATE 240m3/day
SCRAP IRON 9 MT/day
REDUCTION TANKS
PLASTIC OR RUBBER LINED
DUPLICATE PUMPS
STEAM
CHLORINATORS 1 HR. RETENTION
CHLORINE EVAPORATOR 13.6 MT/day
DUPLICATE PUMPS
RECYCLE WATER 127m3/day
EVAPORATOR TRIPLE EFFECT VAC.
FERRIC CHLORIDE 42-45% STORAGE TANKS
110m3/day
63 MT/day

Figure 6. SCHEMATIC DIAGRAM OF FERRIC CHLORIDE RECOVERY FROM SPENT SULFURIC ACID PICKLE LIQUOR (WASTE STREAM NUMBER 8A)

TABLE 13

Capital and Annual Operating Costs for Alternative Treatment of Waste Sulfuric Acid Pickle Liquor (Waste Stream Number 8A)

ANNUAL PRODUCTION (METRIC TONS): 700,000

ANNUAL WASTE (METRIC TONS): DRY WEIGHT 3,200 **WET WEIGHT** 78,700

CAPITAL COST		
FACILITIES		$3,038,400
EQUIPMENT		
Storage Tanks	$ 875,000	
Reduction Tanks	240,000	
Pipeline Mixer	5,500	
Centrifuge	120,000	
Chlorine Evaporator	12,400	
Chlorinator	18,000	
Evaporator	280,000	
Pumps	7,400	
Piping	29,400	
Installation	1,450,700	3,038,400
CONTINGENCY		1,215,400
TOTAL CAPITAL INVESTMENT		$ 7,292,200
ANNUAL COST		
AMORTIZATION		$ 1,188,630
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$ 302,400	
EQUIPMENT REPAIR AND MAINTENANCE	291,690	
MATERIALS	2,126,650	
WASTE DISPOSAL	133,440	
TAXES AND INSURANCE	291,690	3,145,870
ENERGY		36,120
TOTAL ANNUAL COST		$ 4,370,620
RECOVERY VALUE		961,840
NET ANNUAL COST		$ 3,408,780

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS	$ 43.31	$ 55.54
DRY BASIS	1,065.24	1,365.82
COST/METRIC TON OF PRODUCT	4.87	6.24

SHORT TONS = 0.9 x METRIC TON

The centrifuge filtrate flows to reduction tanks where nine metric tons (10 s. tons) of scrap iron are added daily. Chlorine, at a rate of 13.6 metric tons (15 s. tons) per day, is then added to the wastewater which is then pumped to a multiple-effect evaporator. The condensate flows to storage tanks and the water is recycled. Sixty-four man-hours per day are assigned to the operation.

The recovered material, 40% ferric chloride, is valued at $17.60 per metric ton ($16/s. ton). A recovery value was not assigned to the gypsum centrifuge cake.

B. Iron and Steel Production

6. Cold Rolling - Waste Pickle Liquor

b. Hydrochloric Acid
(Waste Stream Number 8B)

Waste Description. Inorganic acids are used to chemically remove oxides and scale from metal surfaces before further metal processing. The pickling process is used most widely in the manufacture of sheet and tin mill products because of relatively low operating costs and ease of production.

The spent hydrochloric acid pickle liquor contains free hydrochloric acid, metal chlorides, oil, inhibitors, and is potentially hazardous.[1]

Analyses of Spent Hydrochloric Acid
Pickle Liquor (Liquid Phase) (mg/l)[1]

Free Hydrochloric Acid	0.5-1.5%
Ferrous Chloride	20-30%
Chromium	7.5
Copper	6.4
Manganese	213
Nickel	11.8
Lead	0.75
Zinc	7.3
Oil and Grease	55

The typical plant producing 700,000 metric tons of steel per year, generates 37,500 metric tons (wet) of waste hydrochloric acid pickle liquor.

Present Waste Disposal Methods. These wastes may be discharged to a receiving stream after dilution with rinsewaters, may be discharged onto open dumps, or may be neutralized with lime before disposal as above. These practices are hazardous to the environment and are receiving the necessary attention for improved disposal procedures.

Recommended Alternative Treatment Method. The trend in the industry has been from sulfuric acid pickle solutions to hydrochloric acid solutions. Hydrochloric acid offers several economic advantages over sulfuric-acid pickle solutions. Spent hydrochloric acid is more suitable for regeneration and recycling than is spent sulfuric acid because of its greater volatility. In addition, regeneration and recycling spent hydrochloric offers a solution to a difficult disposal problem, relating to the high solubility of its lime neutralization salts. The regeneration process for spent hydrochloric acid is generally used on continuous pickling lines.

The spent pickle liquor containing ferrous chloride is sprayed into a reaction chamber that may be either a spray or fluidized bed roaster. Most of the iron oxide formed in the roaster is recovered as pellets in the case of the fluidized bed and as a powdery rouge in the case of the spray roaster. The recovered iron oxide rouges may be sold as a by-product or, if pellets, returned to the steel manufacturing process. Ferric oxide in the roaster off gases is removed in a cyclone. Hydrochloric acid is recovered from the gases in an absorber and returned to the pickling line.

The spent hydrochloric acid regeneration process is being used successfully in full-scale plants throughout the United States, Canada, Europe, and Japan. These vary in size from as little as 3 GPM to 60 GPM.

The process offers many advantages and benefits in that it enables the conversion of a hazardous waste to recycled hydrochloric acid and recovery of iron oxide. The disadvantage of the process is its relatively high capital and operating costs.

The process described in this report is the fluidized bed reactor generating ferric oxide pellets. In the pickle bath, the scale is dissolved with hydrochloric acid to form ferrous chloride and water. The hydrochloric acid concentration decreases as the dissolved ferrous chloride increases.

The spent pickle liquor is pumped through a venturi scrubber where it is concentrated by hot gases coming from the reactor. The concentrated liquor is then pumped to the reactor or fluidized bed roaster. In the roaster, the ferrous chloride is decomposed by high temperatures (Approximately 870°C or 1600°F) to ferric oxide and free hydrochloric acid gas. The ferric oxide pellets, which also constitute the fluidized bed, are removed from the reactor at the same rate as they are formed to maintain a constant bed level. The reactor may be heated by gas or oil with air as the fluidizing agent.

The hot gases leaving the reactor contain hydrochloric acid gas, water vapor, fuel combustion products and small amounts of ferric oxide dust. The dust is separated from the off-gases in a cyclone and recycled to the fluidized bed for pellet growth.

In the aforementioned venturi scrubber, the hot roaster gases are cooled by exchanging heat to the waste pickle liquor as it is pumped into the system. Ferric oxide particles present in the off-gases are also washed out in the venturi scrubber and returned to the reactor.

The cooled hydrochloric acid gases leaving the venturi scrubber are passed into an absorber which is charged with fresh water or pickle rinsewater. The feed rates to the absorber are controlled to yield 18 to 20% hydrochloric acid for recycle to the pickle bath.

Cost for Alternative Treatment Process. A schematic diagram of the alternative waste treatment process is shown in Figure 7. A summary of capital and operating costs are shown in Table 14.

The costs presented are for a Dravo-Lurgi HCl Regeneration Plant. Capital costs were provided by Dravo Corporation. Plant operations require 320 man-hours per week, 52 weeks per year. Annual material requirements consist of 67,200 m^3 (17.8 x 10^6 gallons) of process water and annual energy requirements consist of 69 x 10^9 kg cal (124.8 x 10^9 Btu's) of fuel (natural gas) and about 300 kw (400 hp) electricity.

The recovered material consists of 18% hydrochloric acid which is priced at $15 per metric ton ($13.60/s. ton) which represents about 70% of value. The other recovered material (Fe_2O_3 pellets) is valued at $20 per metric ton ($18/s. ton) of contained iron.

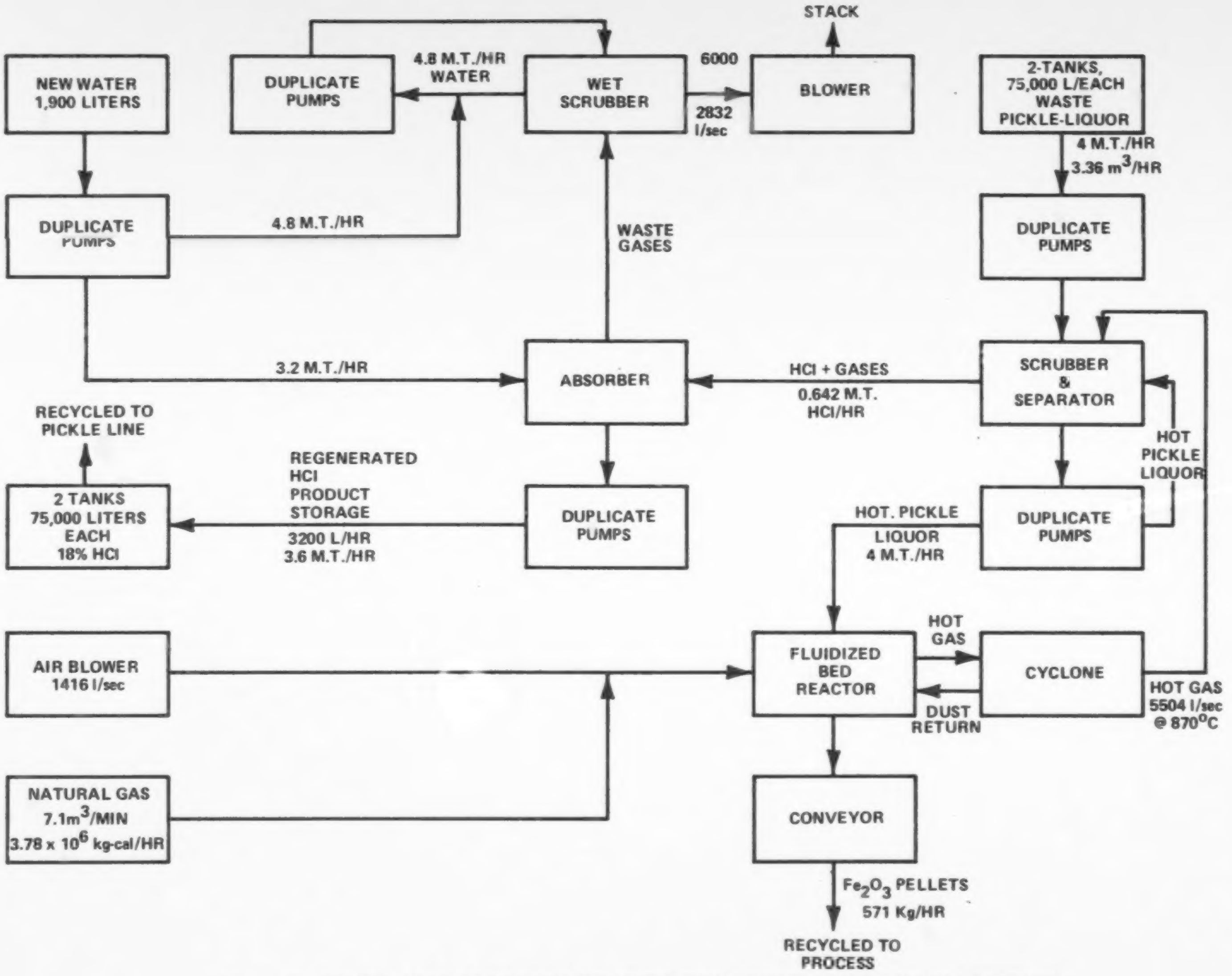

NEW WATER 1,900 LITERS
DUPLICATE PUMPS
4.8 M.T./HR WATER
WET SCRUBBER
6000
2832 l/sec
BLOWER
STACK
2-TANKS, 75,000 L/EACH WASTE PICKLE-LIQUOR
4 M.T./HR
3.36 m3/HR
DUPLICATE PUMPS
4.8 M.T./HR
WASTE GASES
DUPLICATE PUMPS
3.2 M.T./HR
ABSORBER
HCl + GASES
0.642 M.T. HCl/HR
SCRUBBER & SEPARATOR
RECYCLED TO PICKLE LINE
REGENERATED HCl PRODUCT STORAGE
2 TANKS 75,000 LITERS EACH 18% HCl
3200 L/HR
3.6 M.T./HR
DUPLICATE PUMPS
HOT PICKLE LIQUOR
HOT. PICKLE LIQUOR 4 M.T./HR
DUPLICATE PUMPS
AIR BLOWER 1416 l/sec
FLUIDIZED BED REACTOR
HOT GAS
DUST RETURN
CYCLONE
HOT GAS 5504 l/sec @ 870°C
NATURAL GAS 7.1m3/MIN 3.78 x 10^6 kg-cal/HR
CONVEYOR
Fe2O3 PELLETS 571 Kg/HR
RECYCLED TO PROCESS

Figure 7. SCHEMATIC DIAGRAM OF HYDROCHLORIC ACID REGENERATION PROCESS (WASTE STREAM NUMBER 8B)

TABLE 14

Capital and Annual Operating Costs for Waste Hydrochloric Acid Pickle Liquor Regeneration (Waste Stream Number 8B)

ANNUAL PRODUCTION (METRIC TONS): 700,000

ANNUAL WASTE (METRIC TONS): DRY WEIGHT 3,200 WET WEIGHT 37,500

CAPITAL COST		
FACILITIES		
Total		$2,940,000
EQUIPMENT		
CONTINGENCY		588,000
TOTAL CAPITAL INVESTMENT		$3,528,000
ANNUAL COST		
AMORTIZATION		$ 575.060
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$224,640	
EQUIPMENT REPAIR AND MAINTENANCE	141,120	
MATERIALS	5,330	
WASTE DISPOSAL		
TAXES AND INSURANCE	141,120	512,210
ENERGY		352,010
TOTAL ANNUAL COST		$1,439,280
RECOVERY VALUE		509,280
NET ANNUAL COST		$ 930,000

COST/METRIC TON OF WASTE	NET	TOTAL
WET BASIS	$ 24.80	$ 38.38
DRY BASIS	290.63	449.78
COST/METRIC TON OF PRODUCT	1.33	2.06

SHORT TONS = 0.9 x METRIC TON

B. Iron and Steel Production

7. Galvanizing Mill - Acid Rinsewater Neutralization Sludge
(Waste Stream Number 9)

Waste Description. In the steel galvanizing process sheet steel from rolling mills is cleaned, heated and dipped into molten zinc. Prior to galvanizing, surfaces are cleaned with either sulfuric acid or hydrochloric acid. After removal of the metal from the acid pickling tanks, it is rinsed with water and then galvanized. The acid rinsewater is neutralized with lime resulting in dilute lime slurries which upon settling produce lime sludges.

The dry solids generated from neutralization of acid rinsewater amounts to 10.8 kg/MT of steel when sulfuric acid is used for pickling or 2.7 kg/MT of steel when hydrochloric acid is used. The typical steel plant producing 125,000 MT of galvanized steel per year generates 1,350 MT/yr of sludge dry solids (4,500 MT wet) per year when sulfuric acid is used for pickling or 338 MT/yr (1,125 MT wet) when hydrochloric acid is used for pickling.

Sludge from neutralization of acid rinsewater is composed principally of iron metal, iron sulfate, oxides or chlorides and calcium sulfate if sulfuric acid is used. Other sludge constituents are oil and grease and trace amounts of heavy metals, chromium, nickel, copper and lead. Analytical results are similar to those of Waste Streams 7A and 7B.

Present Waste Disposal Method. At the present time, sludges from the neutralization of acid rinsewater are open dumped on land. This practice can pose a threat to ground or surface water quality if oil and grease or leached heavy metals percolate through permeable soils or are carried to surface waters by runoff. Soil and runoff conditions at the individual plant disposal sites would determine the degree of potential hazard to the environment.

Recommended Alternative Treatment Method. When hydrochloric acid pickling is used, the volume of sludge produced is much smaller than when sulfuric acid is used because the calcium chloride generated is water soluble, whereas calcium sulfate from sulfuric acid rinsewater neutralization is relatively insoluble. Each of the sludges will consist chiefly of iron hydrates and may be mixed with the spent mother pickle liquor in which they are soluble. Oil and grease and trace metal content will be similar to that of the mother pickle liquor.

The disposal of acid rinse neutralization sludges on land may be readily eliminated by combining them with spent pickle liquor for recovery of iron and acid. The volume of clarifier underflow sludges from neutralization of acid rinsewater will be 11.5 m^3/day for sulfuric acid rinsewater and 4.5 m^3/day for hydrochloric acid rinsewater. These volumes comprise only a small portion of the daily volume of total spent pickle liquor amounting to about 200 m^3/day. The previous part of this report described processes for iron and acid recovery from spent pickle liquors. Eliminating land disposal of acid rinse neutralization sludges associated with galvanizing obviates any chance of ground or surface water contamination.

Costs for Alternative Treatment Process. The sludge from sulfuric acid rinsewater neutralization is pumped to a tank where it is mixed with spent pickle liquor for treatment. The operation is estimated to require five man-hours each week. The sludge has no recovery value. The flow scheme used for cost development is shown in Figure 8 and its costs are summarized in Table 15.

The sludge from hydrochloric acid rinsewater neutralization is pumped to a tank where it is mixed with spent pickle liquor for treatment. Four man-hours per week are assigned to the operation. The sludge has no recovery value. The flow scheme for cost development is the same as for sulfuric acid rinsewater neutralization sludge and is shown in Figure 8. The costs which reflect one less man-hour per week are summarized in Table 16.

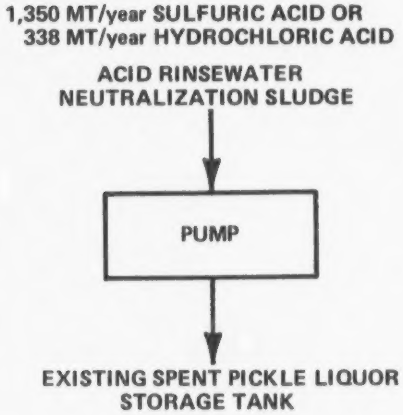

1,350 MT/year SULFURIC ACID OR
338 MT/year HYDROCHLORIC ACID
ACID RINSEWATER
NEUTRALIZATION SLUDGE
PUMP
EXISTING SPENT PICKLE LIQUOR
STORAGE TANK

Figure 8. SCHEMATIC DIAGRAM OF ACID RINSEWATER NEUTRALIZATION SLUDGE RECYCLE (WASTE STREAMS NUMBER 9A, 9B)

TABLE 15

Capital and Annual Operating Costs for Alternative Treatment of Sulfuric Acid Rinse Water Neutralization Sludge (Waste Stream Number 9A)

ANNUAL PRODUCTION (METRIC TONS): 125,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 1,400 **WET WEIGHT** 4,500

CAPITAL COST		
FACILITIES		
EQUIPMENT		
Pump	$ 1,200	
Piping	700	
Installation	1,200	$3,100
CONTINGENCY		600
TOTAL CAPITAL INVESTMENT		$3,700
ANNUAL COST		
AMORTIZATION		$ 600
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$3,510	
EQUIPMENT REPAIR AND MAINTENANCE	150	
MATERIALS		
WASTE DISPOSAL		
TAXES AND INSURANCE	150	$3,810
ENERGY		60
TOTAL ANNUAL COST		$4,470
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS		$0.99
DRY BASIS		3.19
COST/METRIC TON OF PRODUCT		0.04

SHORT TONS = 0.9 x METRIC TON

TABLE 16

Capital and Annual Operating Costs for Alternative Treatment of Hydrochloric Acid Rinse Water Neutralization Sludge (Waste Stream Number 9 B)

ANNUAL PRODUCTION (METRIC TONS): 125,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 300 **WET WEIGHT** 1,000

CAPITAL COST		
FACILITIES		
EQUIPMENT		
Pump	$1,200	
Piping	700	
Installation	1,200	$3,100
CONTINGENCY		600
TOTAL CAPITAL INVESTMENT		$3,700
ANNUAL COST		
AMORTIZATION		$ 600
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$2,810	
EQUIPMENT REPAIR AND MAINTENANCE	150	
MATERIALS		
WASTE DISPOSAL		
TAXES AND INSURANCE	150	$3,110
ENERGY		30
TOTAL ANNUAL COST		$3,740
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS		$ 3.74
DRY BASIS		12.47
COST/METRIC TON OF PRODUCT		0.03

SHORT TONS = 0.9 x METRIC TON

C. Ferroalloys

1. Ferrosilicon Manufacture - Miscellaneous Dusts
(Waste Stream Number 11)

Waste Description. Ferrosilicon is produced in electric submerged-arc furnaces. Emissions are usually controlled by dry-type systems, primarily baghouses. The captured dust is fine and of low density. The quantity of dust generated depends, in part, on the type of alloy being produced. For 75% FeSi, the amount of furnace dust generated averages about 450 kg per metric ton of product, whereas, for 50% FeSi, dust generation averages about 225 kg per metric ton. However, for any given facility, the amounts of dust generated might vary from these average values by a factor of two or more. An average dust generation factor of 338 kg/MT has been assumed for all ferrosilicon production. A typical plant would accumulate about 13,500 MT of furnace dust annually.

The dust is mainly silica, iron oxide, ferrosilicon and lime, with chromium, copper, zinc, manganese, nickel and cobalt combined amounting to less than one percent. Some of these constituents, such as copper, nickel and chromium are leachable but with very low concentrations of less than 0.5 mg/l. Dusts from ferrosilicon production should not be considered potentially hazardous. Dust analyses are shown as follows:[1]

	Ferrosilicon Dust Analysis (ppm)	Solubility Test Filtrate Analysis (mg/l)
Chromium	160	0.3
Copper	2180	0.24
Zinc	1300	< 0.01
Manganese	1500	0.06
Nickel	3250	0.10
Lead	-	< 0.02
Cobalt	82	-
pH	-	9.6

Present Disposal Methods. The furnace dusts generated in the production of ferrosilicon are generally disposed of on land in open piles or in landfill operations. Sometimes the dust is wetted for transport and disposal to minimize dusting. Tests indicate that minimal concentrations of metal constituents may leach into surface or groundwaters.

Recommended Alternative Treatment Method. One method of handling the furnace dust from ferrosilicon production to minimize the potentially adverse leaching effects, should this waste be considered hazardous, involves mixing hydrated lime with the dusts at a dose level of approximately 5 percent by weight. The lime is stored and mixed with the furnace dust when the latter is being transferred to trucks for subsequent disposal. A screw-type conveyor would provide a convenient and efficient means for moving the dusts from a storage bin to waiting trucks. A second screw conveyor could transfer stored lime to the dust conveyor for mixing. A water spray would wet the mixture of dust and lime as it leaves the first conveyor. The wetted mixture would be trucked to a chemical landfill.

Equipment for carrying out liming operations such as those described above is normally available and is used on a routine basis in similar applications in many industries. The action of the lime and water will serve to detoxify the potentially hazardous constituents of the dust.

Cost of Alternative Method of Waste Disposal. A schematic diagram of the alternative method of disposal is shown in Figure 9 and a summary of capital and operating costs is shown in Table 17 .

The dust is mixed with hydrated lime, sprayed with water and hauled to a chemical landfill. The major treatment system equipment components include a 52 m^3 (13,700 gal) dust storage tank, an 18 m^3 (4,800 gal) lime storage tank, a c cm (2 in.) screw conveyor for feeding the lime and a 3 m (10 ft.) long, 23 cm (9 in.) diameter D section conveyor to load the dust/lime mixture into a dump truck.

About 1.9 metric tons (1.7 s. tons) of lime are used daily. The waste sent to the chemical landfill totals 10,160 m^3 (13,200 yd^3) annually. The operation is conducted 3 hours per day and 3 man-hours of labor are assigned. The waste transport cost is included as part of the chemical landfill operation.

The waste has no recovery value.

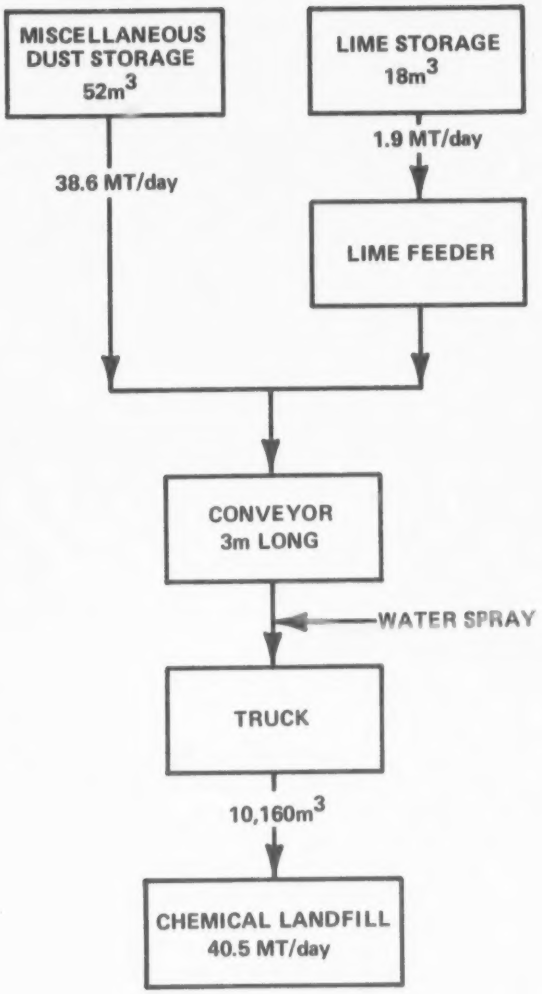

MISCELLANEOUS DUST STORAGE 52m³
LIME STORAGE 18m³
1.9 MT/day
38.6 MT/day
LIME FEEDER
CONVEYOR 3m LONG
WATER SPRAY
TRUCK
10,160m³
CHEMICAL LANDFILL 40.5 MT/day

Figure 9. SCHEMATIC DIAGRAM FOR ALTERNATIVE DISPOSAL OF MISCELLANEOUS DUSTS FROM FERROSILICON MANUFACTURE (WASTE STREAM NUMBER 11)

TABLE 17

Capital and Annual Operating Costs for Alternative Disposal of Miscellaneous Dusts from Ferrosilicon Manufacture (Waste Stream Number 11)

ANNUAL PRODUCTION (METRIC TONS): 40,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 13,500 **WET WEIGHT** -

CAPITAL COST		
FACILITIES		
EQUIPMENT		
Dust Storage Bin	$11,800	
Lime Storage Bin	3,200	
Lime Feeder	2,100	
D Section Conveyor	900	
Piping	300	
Installation	18,000	$36,300
CONTINGENCY		7,300
TOTAL CAPITAL INVESTMENT		$43,600
ANNUAL COST		
AMORTIZATION		$ 7,110
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$ 14,180	
EQUIPMENT REPAIR AND MAINTENANCE	1,740	
MATERIALS	37,180	
WASTE DISPOSAL	152,400	
TAXES AND INSURANCE	1,740	207,240
ENERGY		50
TOTAL ANNUAL COST		$214,400
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS		--
DRY BASIS		$15.88
COST/METRIC TON OF PRODUCT		5.36

SHORT TONS = 0.9 x METRIC TON

C. Ferroalloys

2. Ferrochrome Manufacture - Slag, Dust, and Sludge
(Waste Stream Number 12)

Waste Description. Ferrochrome is produced in electric arc furnaces. The major wastes are furnace slag and captured particulates from control of furnace emissions. The particulates end up as either dust or sludge depending on whether a dry-type or wet-type collection system is used. In some cases both wet and dry systems are used in series, producing both sludge and dust as wastes.

The amount of slag generated in ferrochrome production varies from 1.5 to 2.0 metric tons per metric ton of ferrochrome produced. Captured particulate emissions average about 150 kg per metric ton of ferrochrome production. A typical ferrochrome furnace slag contains about 4% free chromium, 3% chromic oxide (Cr_2O_3), 22% silica (SiO_2), 30% alumina (Al_2O_3), 34% magnesium oxide (MgO), with the remainder consisting primarily of calcium oxide (CaO), ferrous oxide (FeO), and carbon.[4]

The particulate emissions from ferrochrome furnaces contain essentially the same constituents found in the furnace slag, but in somewhat different proportions. Chromic oxide content can exceed 20% with free chrome in the range of 1 to 2%. Magnesium oxide is the most abundant single constituent with concentrations of more than 30% possible. Annually, a typical plant generates about 61,000 metric tons of slag and about 5,300 metric tons of sludge and/or dust from control of furnace emissions.

Analytical data are summarized as follows:

	Typical Analysis (ppm)[1]					Solubility Test Filtrate (mg/l)[1]			
	Slag Coarse	Slag Fine	Furnace Scrubber Sludge	E.P. Dust	Final Lagoon Sludge	Slag Coarse	Slag Fine	Furnace Scrubber Sludge	E.P. Dust
Chromium	4540	3210	1610	3390	1790	0.02	*	190	710
Copper	23	14	35	54	45	0.02	*	0.44	0.20
Lead	< 10	20	70	300	100	0.4	*	1.5	0.7
Zinc	25	70	650	14,000	2500	0.2	*	0.3	0.09
Manganese	500	300	800	7200	2000	9.9	*	8.8	12.3

*Same as slag

Present Methods For Waste Disposal. It is common practice to process ferrochrome slag for recovery of metal values and to sell much of the residual slag for use in road construction. The dusts derived from furnace emission control are generally disposed of on land and covered, while the sludges are accumulated in lagoons. In some cases, the chromium-rich sludge from scrubbers is stored separately in anticipation of future technology that would allow economical processing to recover the metal values. Solubility tests suggest that leaching of chromium and lead from land-disposed furnace emission wastes can pose a potential hazard.[1]

Recommended Alternative Treatment Method. In order to reduce the possibility of leaching potentially hazardous constituents from the residuals that remain after the ferrochrome slag is processed for metal recovery, it is proposed that these residuals be blended with lime. Conveyors would transfer the lime and the residual slag to a rotary blender. The mixture would be loaded on trucks and hauled for use as road building material or hauled to a suitable disposal site.

The dusts and sludge wastes recovered from furnace emission contain significant concentrations of chromium and magnesium with potential for recovery of these metal values. At the present time, the technology for recovery of these metal values is not developed. If one were to detoxify the chromium by conventional reduction precipitation techniques and then chemically landfill the detoxified material, the recovery potential of the chromium would be destroyed. Hence, the alternative disposal process suggested is a secure chemical landfill for storage of the dusts and sludges until technology permits recovery. The sludges will be dewatered in a filter before landfilling.

The proposed processes for treating the wastes generated in ferrochrome production can be expected to greatly reduce the possibility of leaching potentially hazardous constituents when the slag is mixed with lime and used in road construction. The sludges and dusts will be stored in a chemical landfill until technology is developed for recovery of the relatively high metal values.

Alternative Waste Treatment Costs. The slag is mixed with hydrated lime in a 1.5 m^3 (2 yd^3) mixer and transported to a 142 m^3 (5,000 ft^3) loading bin with a bucket elevator. About 8.75 metric tons (9.6 s. tons) of lime are used daily. A small amount of water is added in the process. The operation is conducted 5 hours/day and 4 man-hours are assigned.

The slag can be used for road building. It is valued nominally at $1/metric ton ($0.90/s. ton).

The slag disposal process is described schematically in Figure 10 and disposal costs are summarized in Table 18 .

The dust is sent directly to a chemical landfill. It has no recovery value at present but may in the future with the development of chromium extraction technology. Costs are summarized in Table 19 .

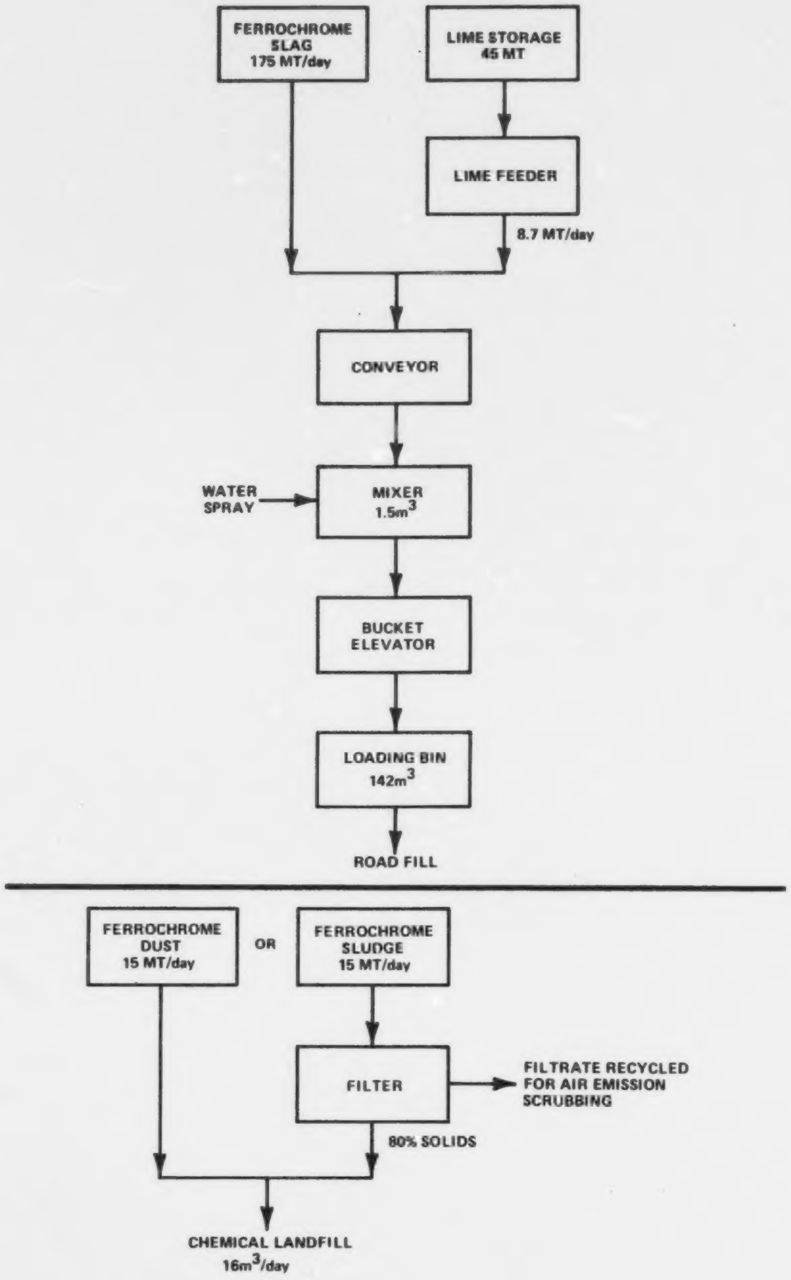

FERROCHROME SLAG 175 MT/day
LIME STORAGE 45 MT
LIME FEEDER
8.7 MT/day
CONVEYOR
WATER SPRAY
MIXER 1.5m^3
BUCKET ELEVATOR
LOADING BIN 142m^3
ROAD FILL
FERROCHROME DUST 15 MT/day
OR
FERROCHROME SLUDGE 15 MT/day
FILTER
FILTRATE RECYCLED FOR AIR EMISSION SCRUBBING
80% SOLIDS
CHEMICAL LANDFILL 16m^3/day

Figure 10. SCHEMATIC DIAGRAM OF ALTERNATIVE TREATMENT FOR DUST, SLUDGE, AND SLAG FROM FERROCHROME MANUFACTURE. (WASTE STREAMS NUMBERS 12A, 12B, 12C)

TABLE 18

Capital and Annual Operating Costs for Alternative Treatment of Slag From Ferrochrome Manufacture (Waste Stream Number 12 A)

ANNUAL PRODUCTION (METRIC TONS): 35,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 61,300 **WET WEIGHT** -

CAPITAL COST		
FACILITIES		
EQUIPMENT		
Lime Storage Bin	$ 5,600	
Lime Feeder	2,100	
Apron Conveyor	20,000	
Mixer	29,000	
Bucket Elevator	7,000	
Loading Bin	26,000	
Piping	400	
Installation	83,200	$173,300
CONTINGENCY		34,700
TOTAL CAPITAL INVESTMENT		$208,000
ANNUAL COST		
AMORTIZATION		$ 33,900
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$ 18,900	
EQUIPMENT REPAIR AND MAINTENANCE	8,320	
MATERIALS	168,440	
WASTE DISPOSAL		
TAXES AND INSURANCE	8,320	203,980
ENERGY		1,810
TOTAL ANNUAL COST		$ 239,690
RECOVERY VALUE		61,300
NET ANNUAL COST		$ 178,390

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS	-	-
DRY BASIS	$2.91	$3.91
COST/METRIC TON OF PRODUCT	5.10	6.85

SHORT TONS = 0.9 x METRIC TON

TABLE 19

Capital and Annual Operating Costs for Alternative Disposal of Dusts from Ferrochrome Manufacture (Waste Stream Number 12B)

ANNUAL PRODUCTION (METRIC TONS): 35,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 5,300 **WET WEIGHT** ____

CAPITAL COST		
FACILITIES		
EQUIPMENT		
CONTINGENCY		
TOTAL CAPITAL INVESTMENT		
ANNUAL COST		
AMORTIZATION		
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL		
EQUIPMENT REPAIR AND MAINTENANCE		
MATERIALS		
WASTE DISPOSAL (Chemical Landfill)	$99,750	$99,750
TAXES AND INSURANCE		
ENERGY		
TOTAL ANNUAL COST		$99,750
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS		-
DRY BASIS		$18.82
COST/METRIC TON OF PRODUCT		2.85

SHORT TONS = 0.9 x METRIC TON

The sludge is filtered and the filter cake is put in a chemical landfill. The filtrate is recycled to air emission scrubbing. The filter is operated 12 hours/day. The sludge sump is sized to hold a 5-day supply of sludge. Approximately 5,520 m^3 (4,250 yd^3) of sludge are landfilled each year. Six man-hours/day are assigned to the operation.

The recovered material has no value at present but may in the future with the development of chromium extraction technology.

The dust and sludge storage in a chemical landfill is also described schematically in Figure 10. Costs are summarized in Table 20.

TABLE 20

Capital and Annual Operating Costs for Alternative Treatment of Sludge from Ferrochrome Manufacture (Waste Stream Number 12)

ANNUAL PRODUCTION (METRIC TONS): 35,000

ANNUAL WASTE (METRIC TONS): DRY WEIGHT 5,300 WET WEIGHT 13,200

CAPITAL COST		
FACILITIES		
Sump	$ 4,200	
Sludge pit	7,900	$ 12,100
EQUIPMENT		
Filter	50,000	
Pump	1,000	
Piping	1,000	
Installation	38,500	90,500
CONTINGENCY		20,500
TOTAL CAPITAL INVESTMENT		$123,100
ANNUAL COST		
AMORTIZATION		$ 20,070
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$ 28,350	
EQUIPMENT REPAIR AND MAINTENANCE	4,920	
MATERIALS		
WASTE DISPOSAL (Chemical Landfill)	121,440	
TAXES AND INSURANCE	4,920	$159,630
ENERGY		3,450
TOTAL ANNUAL COST		$183,150
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	NET	TOTAL
WET BASIS		$13.88
DRY BASIS		34.56
COST/METRIC TON OF PRODUCT		5.23

SHORT TONS = 0.9 x METRIC TON

C. Ferroalloys

3. Silicomanganese Manufacture - Slag and Scrubber Sludge (Waste Stream Number 13)

Waste Description. Silicomanganese is produced in submerged-arc electric furnaces. A greenish, glassy-textured slag is generated at the rate of approximately 600 kg per metric ton of silicomanganese produced. Control of furnace fumes is accomplished by either wet or dry systems with collection of particulates at the rate of 95 to 100 kg per metric ton of product. In some cases, the dusts collected by the dry systems are slurried with water for ease of handling and transport. A typical plant might generate 24,000 MT of slag annually and collect 3,900 MT of particulates as dust or sludge from control of furnace emission.

The major constituents of silicomanganese slag are silica (SiO_2) and alumina (Al_2O_3), each at a concentration of about 30 percent by weight. Calcium oxide (CaO), magnesium oxide (MgO), manganese oxide (MnO) and manganese account for most of the remaining 40 percent. Chromium, copper, lead and zinc are found in approximately equal amounts varying from 20 to 30 ppm[1].

Silicomanganese slag is essentially an aluminum silicate containing about 5-7% manganese. Solubility tests on filtrates show almost complete insolubility as follows:

Solubility Tests on Filtrates (mg/l)[1]

Chromium	< 0.01	Nickel	< 0.05
Copper	0.17	Lead	< 0.2
Zinc	0.05	pH	6.8
Manganese	0.1		

Resource recovery is not indicated for this waste. Because of its extensive use in road building, this waste is a useful material for construction.

Furnace particulate sludges consist mainly of silica (25%) and manganese oxide (21%) with potassium oxide sometimes exceeding 15%. Lead and zinc are present in concentrations of about 2.5% and 1.0%, respectively. Chromium and copper concentrations are considerably lower at about 45 and 82 ppm, respectively. These analyses are shown as follows:

	Silicomanganese Sludge Dry Basis (ppm)[1]
Chromium	45
Copper	82
Lead	25,000
Zinc	10,000
Manganese	300,000

The analyses of the filtrates from solubility tests on silicomanganese sludge are shown following:

Solubility Test Filtrate Analyses[1]
(mg/l)

	Silicomanganese Sludge
Chromium	0.55
Copper	0.14
Zinc	0.03
Manganese	< 0.02
Nickel	< 0.05
Lead	1.3
pH	11.0

Present Waste Handling Methods. The furnace slag derived from silicomanganese production is frequently sold to local contractors for use as fill. Slag that is not sold is stored or deposited in open piles. The sludges resulting from the capture of furnace emissions are generally accumulated in lagoons or settling basins. The sludges are periodically removed from the settling areas and dumped on land.

Solubility tests indicate that silicomanganese slag is virtually insoluble. Therefore, leaching is not expected to present adverse environmental effects. On the other hand, tests on dusts and sludges from furnace emission control have shown that leaching of lead might present a problem and it is suggested that alternative methods of disposing of these wastes might be required to prevent a potentially hazardous environmental condition.[1]

Recommended Alternative Treatment Method. In the case of silicomanganese slag, the present methods for disposal are considered adequate. Much, if not most, of the slag ends up as fill for road construction.

Resource recovery by reduction roasting is proposed for dusts and sludges from furnace emission control. The treatment process is based on the Waelz kiln, a process which was originally developed by Krupp Grusonwerke in Germany in 1925. The same system is recommended for handling scrubber sludges generated in the production of ferromanganese. Ferromanganese and silicomanganese are commonly produced at the same plant since the slag from ferromanganese production is used as raw material for silicomanganese production. Thus, it is desirable to have a system that can handle sludges and dusts from both types of ferroalloy furnaces.

A flowsheet for the system is shown in Figure 11. Thickened sludges from the ferromanganese and silicomanganese furnaces are filtered for dewatering. The combined sludges are then mixed with a reductant, such as coke breeze or a mixture of coke breeze and iron powder, and pelletized. The pellets

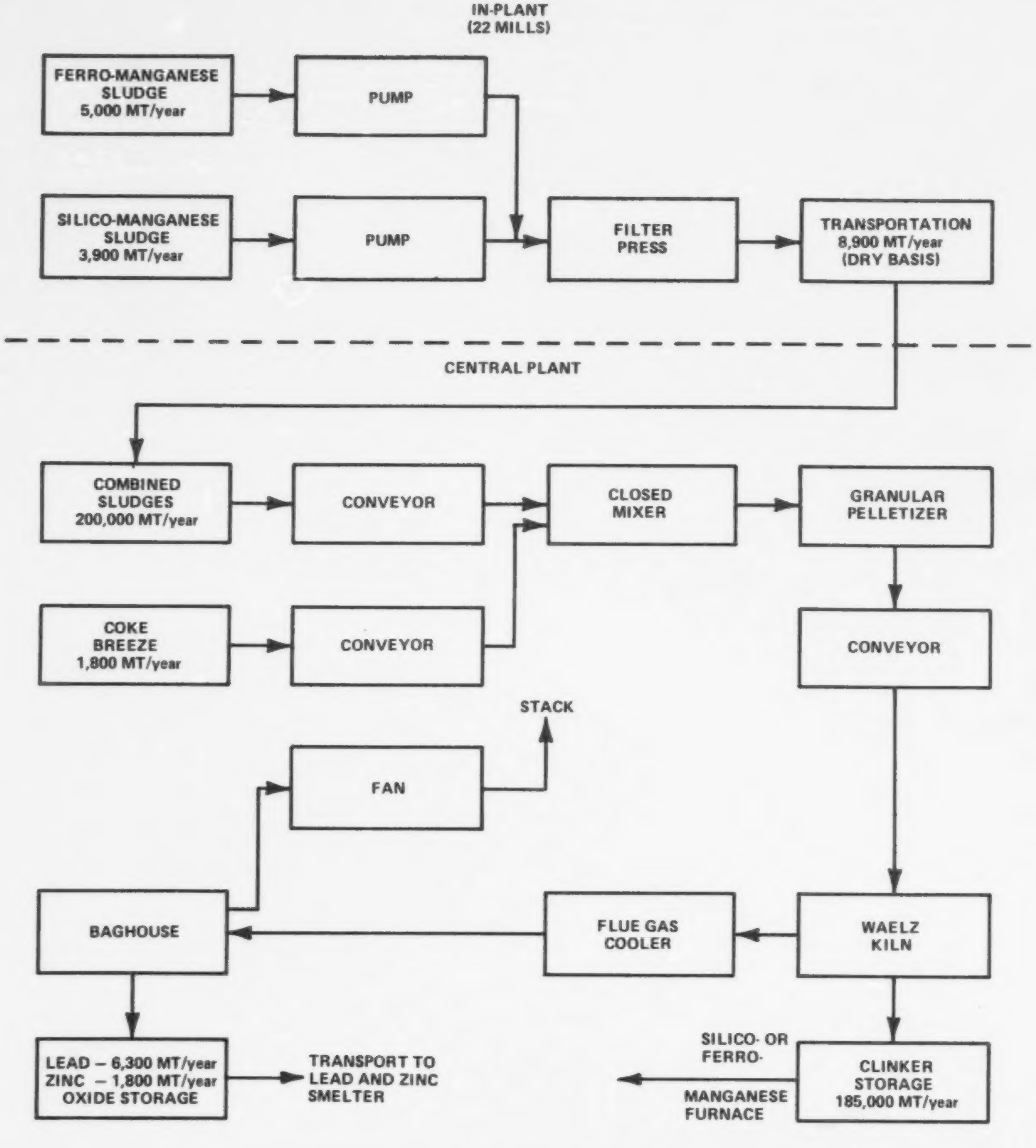

IN-PLANT
(22 MILLS)
FERRO-MANGANESE SLUDGE 5,000 MT/year
PUMP
SILICO-MANGANESE SLUDGE 3,900 MT/year
PUMP
FILTER PRESS
TRANSPORTATION 8,900 MT/year (DRY BASIS)
CENTRAL PLANT
COMBINED SLUDGES 200,000 MT/year
CONVEYOR
CLOSED MIXER
GRANULAR PELLETIZER
COKE BREEZE 1,800 MT/year
CONVEYOR
CONVEYOR
STACK
FAN
BAGHOUSE
FLUE GAS COOLER
WAELZ KILN
LEAD – 6,300 MT/year
ZINC – 1,800 MT/year
OXIDE STORAGE
TRANSPORT TO LEAD AND ZINC SMELTER
SILICO- OR FERRO-
MANGANESE FURNACE
CLINKER STORAGE 185,000 MT/year

Figure 11. SCHEMATIC DIAGRAM OF ALTERNATIVE TREATMENT FOR SLUDGES FROM SILICO AND FERRO-MANGANESE MANUFACTURE. (WASTE STREAM NUMBERS 13 AND 14)

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are then roasted in a Waelz kiln which is a rotating furnace that resembles a cement kiln. The unit is fired by a burner at the lower end. The temperature of the bed exceeds 1100°C. Fumes from the kiln, which contain lead and zinc oxides are collected in a baghouse. The clinker from the kiln is rich in manganese and might be suitable for feed material for the ferromanganese or silicomanganese furnace.

The first Waelz kiln was installed by Krupp Grusonwerke at Magdeburg (Germany) in 1925 in order to distill zinc oxide from various zinc bearing oxide ores and residues. A number of additional kilns have been installed and are operated by zinc producers. It has been reported that New Jersey Zinc Company has abandoned its use of a Waelz kiln for processing complex zinc-manganese iron ore containing relatively high zinc concentrations.

In 1974, Sotetsu Metal was founded in Japan as a joint venture of Nisso Kinzoku and 23 steel mills. Sotetsu has agreed to collect dusts containing more than 20% zinc and to treat them in a Waelz kiln having a nominal capacity of 60,000 tons per year. The residual clinker may still contain too much zinc to be recycled to the steel plant and this is one of the reported operating difficulties.

In 1974 and 75, two industrial Waelz kilns with approximately 10,000 tons of zinc-ferrous in-plant fines were installed at the Waelz plant of Berzelius Metallhutten GmbH, a sister company of Lurgi in the Metallgesellschaft group. Lurgi claims 90% Zn removal.

The alternative system for handling sludges would eliminate the potential threat of leaching lead and zinc and at the same time would allow recovery of these marketable constituents. However, further investigation is required to determine the feasibility of processing residues that contain zinc and lead concentrations less than 5 percent. The process has usually been applied to materials having zinc concentration greater than 20 percent. Also, further study is necessary to evaluate the practicality of recycling the manganese-rich residues to the silicomanganese furnace.

Cost of Alternative Method of Waste Disposal. These costs are developed from Figure 11 on sludges from silico and ferromanganese manufacture plus wastes from other industries generating similar wastes that can be processed in the Waelz kiln. The costs are summarized in Tables 21 and 22.

Table 21 summarizes the costs for waste preparation at each individual plant and Table 22 summarizes the costs for a central processing plant serving 22 individual mills. Approximately seven of these mills are ferroalloy plants with the remainder being other industries having similar wastes containing lead and/or zinc. The waste treatment/recovery operations involves two operations at different locations.

TABLE 21

Individual Plant Capital and Annual Operating Costs for Alternative Treatment of Silico and Ferromanganese Sludges (Waste Stream Numbers 13 and 14)

ANNUAL PRODUCTION (METRIC TONS): 30,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 8,900 **WET WEIGHT** 22,200

CAPITAL COST		
FACILITIES		
Sludge Pits		$ 7,200
EQUIPMENT		
Filter	$79,000	
Pumps	1,800	
Piping	1,300	
Installation	61,100	143,200
CONTINGENCY		30,100
TOTAL CAPITAL INVESTMENT		$180,500
ANNUAL COST		
AMORTIZATION		$ 29,420
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$28,350	
EQUIPMENT REPAIR AND MAINTENANCE	7,220	
MATERIALS		
WASTE DISPOSAL		
TAXES AND INSURANCE	7,220	42,790
ENERGY		4,080
TOTAL ANNUAL COST		$ 76,290
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS		$3.44
DRY BASIS		8.57
COST/METRIC TON OF PRODUCT		2.54

SHORT TONS = 0.9 x METRIC TON

TABLE 22

Central Plant Capital and Annual Operating Costs for Alternative Treatment (Waelz Kiln) of Silico and Ferromanganese Sludges (Waste Stream Numbers 13 & 14)

ANNUAL PRODUCTION (METRIC TONS): 660,000 (22 plants)

ANNUAL WASTE (METRIC TONS): DRY WEIGHT 198,000 **WET WEIGHT** 495,000

CAPITAL COST		
FACILITIES		$8,432,100
EQUIPMENT		
Sludge Conveyors	$ 40,000	
Coke Breeze Conveyors	10,200	
Mixer	27,200	
Granular Pelletizer	100,000	
Waelz Kiln	2,750,000	
Bag House	560,000	
Flue Gas Cooler	12,900	
Air Fan	35,300	
Installation	4,896,500	8,432,100
CONTINGENCY		1,686,400
TOTAL CAPITAL INVESTMENT		$18,550,750
ANNUAL COST		
AMORTIZATION		$ 3,023,750
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$ 453,600	
EQUIPMENT REPAIR AND MAINTENANCE	742,020	
MATERIALS	2,000,000	
WASTE DISPOSAL *	1,200,000	
TAXES AND INSURANCE	742,020	5,137,640
ENERGY		106,290
TOTAL ANNUAL COST		$8,267,680
RECOVERY VALUE		767,450
NET ANNUAL COST		$7,500,230

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS	$15.15	$16.70
DRY BASIS	37.88	41.76
COST/METRIC TON OF PRODUCT	11.36	12.53

*Waste transport to processing facility

SHORT TONS = 0.9 x METRIC TON

The first operation is conducted at each mill. It consists of filtering the silico- and ferromanganese sludges. The filter is operated 12 hours each day and is assigned 6 man-hours per day. Costs for this operation are shown in Table 21 .

The filter cake discharge is then shipped to a centrally located waste treatment/recovery plant. This plant is sized to accept the dewatered sludges from about 22 mills. The central plant has an annual capacity to process about 200,000 metric tons (220,000 s. tons) (dry weight) of sludge. The sludge is mixed with coke breeze in a mixer with a 3,400 kg (7,500 lb) capacity, pelletized in a 2.4 m (8 ft) diameter granular pelletizer and then roasted in a Waelz kiln. The contained coke breeze serves as fuel. The operation is estimated to require 96 man-hours per day.

Costs for this operation are shown in Table 22 . Facility costs for this operation are estimated to be equal to the installed equipment costs. Costs of this magnitude are estimated since this is a new operation rather than an add-on to an existing plant.

The major metal recovered is zinc. It is assumed that the silico- and ferromanganese sludges contain 3.5% and 1% zinc, respectively and that the process results in 90% recovery. The recovered zinc oxide is valued at $204 per metric ton ($185/s. ton) which is 25% of the metal value.

The plant also generates about 185,000 metric tons (203,500 s. tons) of clinker each year. This material contains manganese and with the removal of zinc and lead may be suitable for reprocessing. No value has been assigned to this material nor are costs included for its disposal as landfill.

The capital and annual costs for each of the 22 mills, assuming a pro-rated share of the centralized waste treatment/recovery plant are:

Capital Costs	
In-plant	$180,500
Processing Plant (Pro-rated share)	843,200
TOTAL	$1,023,700
Annual Costs	
In-plant	$375,800
Processing Plant (Pro-rated share)	76,290
TOTAL	$452,090
Recovered Material Value	34,880
Net Annual Cost	$417,210

Cost/Metric Ton of Waste	Net	Total
Wet Basis	$18.79	$20.36
Dry Basis	46.88	50.80
Cost/Metric Ton of Product	13.91	15.07

C. Ferroalloys

4. Ferromanganese Manufacture - Slag and Sludge
(Waste Stream Number 14)

Waste Description. The production of ferromanganese generates slag at the rate of about 600 kg per metric ton of alloy produced. The major constituents of the slag are manganese (either as free metal or the oxide) at greater than 50 percent concentration, and silica (SiO_2) and alumina (Al_2O_3), each at concentrations of 17 to 21 percent. Minor constituents include copper at 310 ppm, chromium at 100 ppm, lead at 10 ppm, and zinc at 20 ppm.[1]

Analyses of filtrates from solubility tests of ferromanganese slag are as follows (mg/l)[1]:

Chromium	0.02	Nickel	< 0.05
Copper	0.04	Lead	< 0.02
Zinc	0.03	pH	5.9
Manganese	2.1		

Significant concentrations of toxic heavy metals did not leach and this slag is not considered hazardous at this time.

The control of furnace emissions with wet scrubber systems produces a sludge which contains about 3.5 percent zinc, 0.5 percent lead, 2.0 percent manganese, 50 ppm of copper, and 18 ppm of chromium.[1]

Filtrate analyses of ferromanganese baghouse dust solubility tests showed relatively high values of copper, zinc, manganese and lead.[1]

Solubility Test
Filtrate Analyses (mg/l)

	Ferromanganese Baghouse Dust
Chromium	0.2
Copper	4.5
Zinc	110
Manganese	7.5
Nickel	0.53
Lead	560
pH	9.7

In some plants, the scrubber liquor is simply diverted to a lagoon or settling basin where particulate matter settles out in amounts corresponding to 150 kg/MT of ferromanganese produced. In other plants, lime is added to the scrubber liquor and a clarifier is used to promote settling of solids. The underflow from the clarifier is piped to lagoons where the sludge is accumulated in amounts of about 165 kg/MT of product.

A plant producing 30,000 MT of ferromanganese per year would generate about 18,000 MT of slag and 5,000 MT of limed sludge annually.

Present Waste Disposal Methods. As noted under the discussion of silicomanganese wastes, it is common practice to produce both silicomanganese and ferromanganese at the same plant. Slag from the production of ferromanganese is used as feed material for silicomanganese production or as feedstock for electrolytic manganese. Thus, in general, ferromanganese slag is not considered a waste because of its high manganese content and is, in fact, recycled. Tests indicate that leachate from slag storage piles would probably be environmentally acceptable.

The sludge derived from the control of furnace emissions in ferromanganese production is accumulated in lagoons, sold as a fertilizer additive, or recycled. In some cases, the bottom deposits of the lagoons are dredged occasionally and deposited in an open dump area. Solubility tests performed on furnace emission particulates indicate a significant potential for leaching of lead and zinc.[1]

Recommended Alternative Treatment Method. It is proposed that the sludges resulting from the control of furnace emissions in silicomanganese and ferromanganese production plus similar wastes from other industries be handled by a single processing system as described in the previous section on silicomanganese wastes. The sludges would be pelletized and reduction roasted to vaporize lead and zinc for recovery as the oxides. This approach would eliminate the problems of lead and zinc leaching and at the same time allow recovery of these metals for reuse. As noted, however, further study is required to establish the practicality of this system.

Cost for Alternative Method of Waste Disposal. The process scheme for the alternative treatment shown in Figure 11 is summarized for costs in Tables 21 and 22 .

SECTION II

PRIMARY NON-FERROUS SMELTING AND REFINING HAZARDOUS WASTES

A. Copper Smelting-Acid Plant Blowdown Sludge
(Waste Stream Number 15)

Waste Description. Large amounts of sulfur dioxide (SO_2) gas are generated from roasting sulfide copper ore concentrates. Most copper smelters have a sulfuric acid by-product plant to recover SO_2 as sulfuric acid. The sulfuric acid recovery process generates a waste blowdown slurry. The typical smelter operation producing 285 MT of blister copper per day will generate 2270 m^3/day of blowdown slurry from the sulfuric acid recovery plant. This slurry will contain about 2% solids. The pH of the blowdown can be as low as 3.0. The settleable solids generation rate is 3 kg/MT of blister copper produced. The typical copper smelter producing 100,000 MT/yr of copper metal will generate 270 MT/yr of blowdown settleable solids.

Blowdown sludges contain the following concentrations of elements:[1]

	Sludge Analyses Dry Bases (ppm)	Solubility Test Filtrate Analyses (mg/l)
Arsenic	-	0.805
Cadmium	520	8.4
Silicon	500	0.5
Copper	279,400	850
Mercury	0.8	-
Manganese	89	1.0
Nickel	110	0.64
Lead	8,000	7.8
Antimony	500	0.2
Selenium	30	-
Zinc	27,900	300
pH	-	3.0

Major constituents of the slurry solids are metallic oxides, and sulfates. Copper is present in high concentrations and may approach 25-30% of the solids content. Zinc and lead are also present in appreciable concentration. Other metals present in trace amounts include cadmium, nickel, antimony, and selenium.

Major metal components of dissolved solids include iron, copper, and zinc. These will be present as sulfates and sulfites. The presence of a number of toxic heavy metals in significant concentrations (i.e., copper, zinc, cadmium, lead, and selenium), and soluble salts, impose a potential hazard from land disposal of copper smelter acid plant blowdown.

Present Methods for Waste Handling. Typically, smelter acid plant blowdown effluent is sent to a thickener where thickened solids are recovered and recycled to the smelter for copper values. Overflow from the thickener containing suspended solids and dissolved solids is discharged to tailing ponds associated with the mining and milling complex. Recycle of thickener underflow is a desirable resource recovery operation, that is generally carried out.

The thickener overflow contains appreciable concentrations of dissolved solids and an estimated 0.77 MT/day of residual suspended solids. These dissolved and suspended solids include the toxic heavy metals copper, lead, cadmium, and arsenic, which pose potential ground and surface water environmental hazards if these percolate through unlined tailings ponds where they are being discharged.

Recommended Alternative Treatment Method. The present method for waste handling would be improved by further treatment and clarification of thickener overflow to remove residual suspended solids leaving the existing thickener and to precipitate the toxic components of the dissolved solids.

The alternative suggested is shown schematically in Figure 12. The thickener overflow is treated with precipitating and flocculating chemicals such as lime in a clari-flocculator. The clari-flocculator overflow may be discharged to the tailings pond. The precipitated solids in the clarifier underflow are centrifuged for a chemical landfill and the centrifugate is recycled to the clarifier.

The proposed alternative process precludes potential environmental hazards by removing residual copper bearing suspended solids and hazardous dissolved solids before discharging thickener overflow to the tailings pond.

Cost of Alternative Treatment. The costs for the process scheme described in Figure 12 are summarized in Table 23 and are based on the following assumptions.

The major treatment system components are a 1.89 m^3 (500 gal) flocculant feed system, a 23 m^3 (800 ft^3) lime silo and automatic feeder, a 200 m^3 (30' x 10') clarifier, a centrifuge, storage tanks and pumps. Hydrated lime is added at the clarifier at a rate of 3.3 metric tons (3.6 s. tons) per day. Flocculant addition to the wastewater flow is at a rate of 5 ppm.

The overflow from the clarifier is discharged. The underflow is centrifuged and generates about 9.8 m^3 (2,600 gal) of cake daily, which is then sent to a chemical landfill. The filtrate is recycled to the clarifier.

Six man-hours are assigned to the operation per day. No material value is recovered.

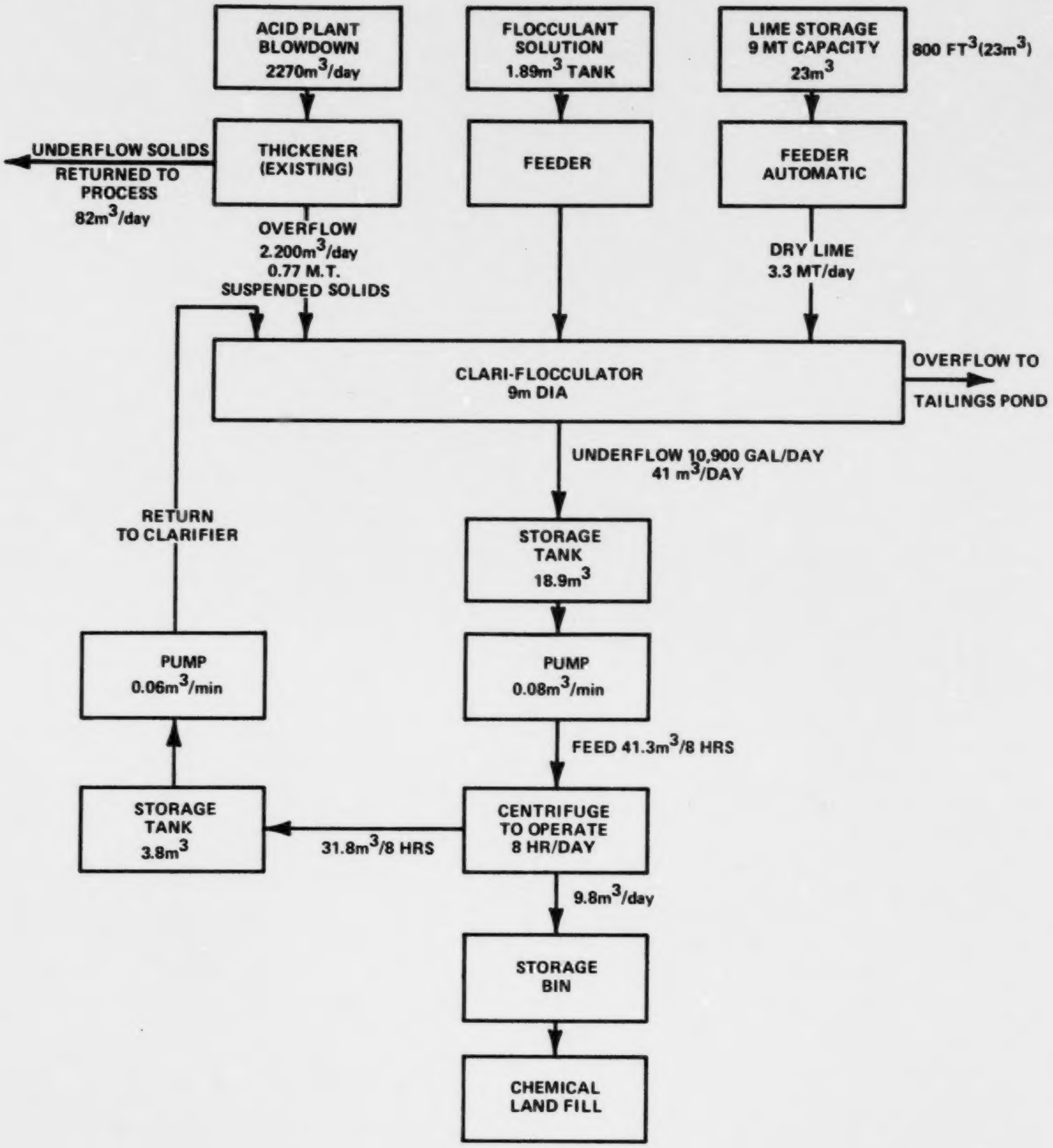
ACID PLANT BLOWDOWN 2270m3/day
FLOCCULANT SOLUTION 1.89m3 TANK
LIME STORAGE 9 MT CAPACITY 23m3
800 FT3(23m3)
UNDERFLOW SOLIDS RETURNED TO PROCESS 82m3/day
THICKENER (EXISTING)
FEEDER
FEEDER AUTOMATIC
OVERFLOW 2.200m3/day 0.77 M.T. SUSPENDED SOLIDS
DRY LIME 3.3 MT/day
CLARI-FLOCCULATOR 9m DIA
OVERFLOW TO TAILINGS POND
UNDERFLOW 10,900 GAL/DAY 41 m3/DAY
RETURN TO CLARIFIER
STORAGE TANK 18.9m3
PUMP 0.06m3/min
PUMP 0.08m3/min
FEED 41.3m3/8 HRS
STORAGE TANK 3.8m3
31.8m3/8 HRS
CENTRIFUGE TO OPERATE 8 HR/DAY
9.8m3/day
STORAGE BIN
CHEMICAL LAND FILL

Figure 12. FLOW DIAGRAM FOR ALTERNATIVE TREATMENT OF PRIMARY COPPER SMELTING - ACID PLANT BLOWDOWN (WASTE STREAM NUMBER 15)

TABLE 23

Capital and Annual Operating Costs for Alternative Treatment of Acid Plant Blowdown Sludge - Primary Copper Smelting (Waste Stream Number 15)

ANNUAL PRODUCTION (METRIC TONS): 100,000

ANNUAL WASTE (METRIC TONS): DRY WEIGHT 300 **WET WEIGHT** 700

CAPITAL COST		
FACILITIES		
Sump		$ 5,300
EQUIPMENT		
Lime Precipitation System	$ 26,100	
Flocculant Feed System	3,500	
Clarifier	42,000	
Tanks	4,300	
Centrifuge	58,000	
Pumps	1,900	
Piping	10,300	
Installation	121,300	267,400
CONTINGENCY		53,500
TOTAL CAPITAL INVESTMENT		326,200
ANNUAL COST		
AMORTIZATION		$ 53,170
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$28,350	
EQUIPMENT REPAIR AND MAINTENANCE	13,050	
MATERIALS	71,080	
WASTE DISPOSAL	82,320	
TAXES AND INSURANCE	13,050	207,850
ENERGY		4,470
TOTAL ANNUAL COST		265,490
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS		379.27
DRY BASIS		884.97
COST/METRIC TON OF PRODUCT		2.65

SHORT TONS = 0.9 x METRIC TON

B. Electrolytic Copper Refining - Mixed Sludge
(Waste Stream Number 16)

Waste Description. In the electrolytic refining of copper, relatively pure copper anodes (99.5% copper) are dissolved in sulfuric acid and copper is electrolytically deposited to produce higher purity cathode copper (99.9%). A number of dilute miscellaneous effluents are wasted in the electrolysis process. These include contact cooling water from quenching hot anode or cathode copper, spent anode washings, spent electrolyte and plant washdown. The flow of dilute acid slurry from a typical electrolytic refinery producing 460 MT of refined copper per day is 6,800 m^3/day. Suspended solids content is 210 kg/day and dissolved solids content 870 kg/day. Total dissolved and suspended solids in the miscellaneous effluents amount to 2.4 kg/MT of copper produced or 384 MT/yr.

The settled sludge solids contain 2% copper, 1% lead, and significant concentrations of cadmium, mercury, antimony, selenium and zinc. This waste is considered potentially hazardous because of the possibility that these toxic constituents may leach in concentrations sufficient to pose a threat to ground water quality.[1]

Analysis of The Dredged Solids[1] (ppm)

Cadmium	180	Nickel	10
Chromium	25	Lead	12,000
Copper	22,000	Antimony	800
Mercury	5	Selenium	550
Manganese	8	Zinc	190

Present Method for Waste Handling. Wastewaters from electrolytic copper refining are currently clarified in unlined lagoons or tailings ponds and the settled solids are dredged and deposited on land. These practices are environmentally inadequate because significant concentrations of toxic heavy metals as described above may leach and percolate through permeable soils or rock strata to ground water.

Recommended Alternative Treatment Method. The major portion of potentially hazardous pollutants from electrolytic refining sludges are contained in the dissolved salts. Lime treatment of the wastewaters will remove the heavy metal pollutants from the water phase. It is uneconomical to recycle the settled solids for the recovery of copper and/or lead value. The sludge solids are then deposited in a secure chemical landfill.

Figure 13 presents a lime treatment process for removal of suspended and dissolved solids from copper electrolytic refining wastewaters and subsequent sludge disposal in a chemical landfill. Wastewaters are limed and clarified in a clari-floccular. The settled sludge amounting to 0.9 MT/day (8,000 gal/day) is pumped to a centrifuge for dewatering. The filtrate from the centrifuge amounting to approximately 22 m^3/day (5,800 gal/day) is recycled to the clari-flocculator. After centrifuge dewatering, 9 MT/day of sludge containing 0.9 MT/day solids will be put into metal drums and transported to a

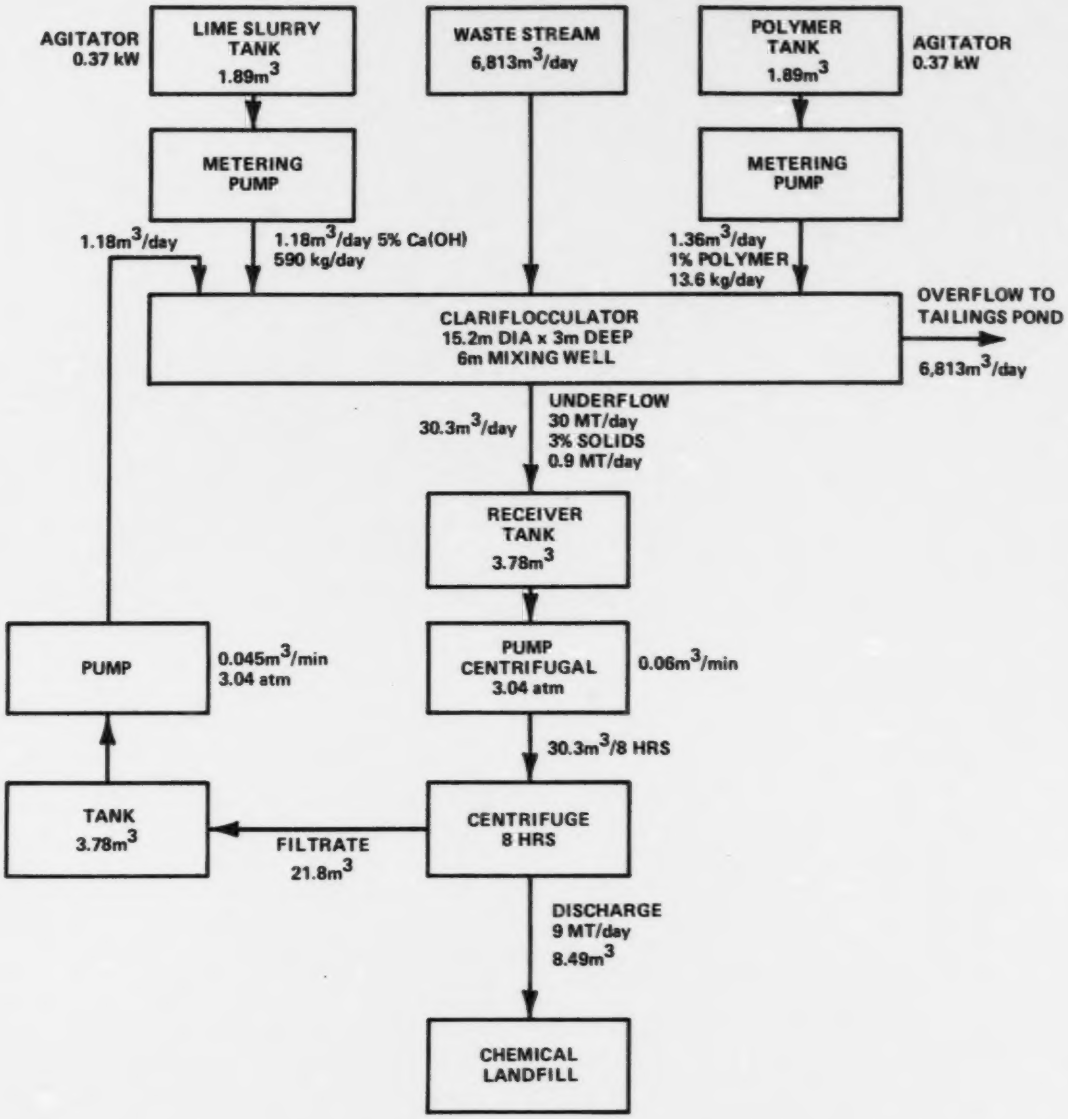
AGITATOR
0.37 kW
LIME SLURRY TANK
1.89m3
WASTE STREAM
6,813m3/day
POLYMER TANK
1.89m3
AGITATOR
0.37 kW
METERING PUMP
METERING PUMP
1.18m3/day
1.18m3/day 5% Ca(OH)
590 kg/day
1.36m3/day
1% POLYMER
13.6 kg/day
CLARIFLOCCULATOR
15.2m DIA x 3m DEEP
6m MIXING WELL
OVERFLOW TO TAILINGS POND
6,813m3/day
30.3m3/day
UNDERFLOW
30 MT/day
3% SOLIDS
0.9 MT/day
RECEIVER TANK
3.78m3
PUMP
0.045m3/min
3.04 atm
PUMP CENTRIFUGAL
3.04 atm
0.06m3/min
30.3m3/8 HRS
TANK
3.78m3
FILTRATE
21.8m3
CENTRIFUGE
8 HRS
DISCHARGE
9 MT/day
8.49m3
CHEMICAL LANDFILL

Figure 13. FLOW DIAGRAM OF ALTERNATIVE TREATMENT PROCESS FOR MIXED SLUDGES FROM ELECTROLYTIC COPPER REFINING (WASTE STREAM NUMBER 16)

chemical landfill. It is estimated that forty-three 55-gallon drums would be chemically landfilled each day.

Potential leaching of toxic metal constituents is precluded by treating electrolytic sludge slurry with lime followed by disposal in a chemical landfill. Neither of these practices is being used by the industry at the present time.

Cost for Alternative Method of Waste Disposal. Waste treatment costs are shown in Table 24. A relatively small amount of hydrated lime 590 kg (1,300 lb) and flocculant 13.6 kg (30 lb) per day are added to the wastewater. Following settling in a 560 m^3 (50' x 10') clarifier, the underflow is collected in a receiving tank and then pumped to a centrifuge. The daily centrifuge discharge amounts to about 8.5 m^3 (2,244 gal) which is containerized and sent to a chemical landfill. The centrifuge filtrate is recycled to the clarifier.

Eight hours of labor are assigned to the operation daily. The recovered material has no value.

TABLE 24

Capital and Annual Operating Costs for Alternative Treatment of Mixed Sludge From Primary Electrolytic Copper Refining (Waste Stream Number 16)

ANNUAL PRODUCTION (METRIC TONS): 160,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 400 **WET WEIGHT** 1,100

CAPITAL COST		
FACILITIES		
EQUIPMENT		
Lime Precipitation System	$11,400	
Flocculant Feed System	3,500	
Clarifier	60,000	
Holding Tanks	2,400	
Centrifuge	42,000	
Pumps	2,100	
Piping	13,400	
Installation	110,900	$245,700
CONTINGENCY		49,100
TOTAL CAPITAL INVESTMENT		$294,800
ANNUAL COST		
AMORTIZATION		$ 48,050
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$ 37,800	
EQUIPMENT REPAIR AND MAINTENANCE	11,790	
MATERIALS	20,880	
WASTE DISPOSAL	263,290	
TAXES AND INSURANCE	11,790	$345,550
ENERGY		2,850
TOTAL ANNUAL COST		$396,450
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS		$360.40
DRY BASIS		991.13
COST/METRIC TON OF PRODUCT		2.48

SHORT TONS = 0.9 x METRIC TON

C. Lead Smelting - Sludges
(Waste Stream Number 17)

Waste Descriptions.

1. Acid Plant Blowdown and Miscellaneous Slurries. Before lead ore concentrates are reduction roasted to metal in a blast furnace, the fine particles of the charge are agglomerated in a sintering machine. The sinter machine fuses the lead concentrates and other lead bearing residues with lime and silica.

Sulfur contained in the lead ore concentrate is driven off as SO_2 gas at the sinter machine. Since copious amounts of SO_2 are generated, acid plants are built to recover SO_2 as sulfuric acid where possible. In the production of the sulfuric acid, a blowdown slurry is wasted. This slurry is called acid plant blowdown. It is treated with lime and results in 230 m^3/day containing 6.3 MT of solids for a typical plant producing 314 MT/day of lead metal.

Miscellaneous dusts such as sweepings are slurried and combined with cleanup water and cadmium plant effluent in secondary operations. These wastes are lime treated in conjunction with acid plant blowdown. Approximately 230 m^3 of miscellaneous slurries containing 6.3 MT of solids are produced each day at the typical plant. The solids generation rate for combined acid plant blowdown and miscellaneous slurries is 40 kg/MT of lead metal produced.

Sludges resulting from the acid plant blowdown and miscellaneous slurries contain recoverable amounts of lead and zinc and significant concentrations of cadmium, copper and mercury and are considered potentially hazardous.[1] These are summarized in the following table :

		Solubility Test Filtrate Analyses mg/l	
	Dried Sludges Analyses ppm	Sinter Scrubber Sludge	Acid Plant Lagoon Dredging
Arsenic	-	-	0.231
Cadmium	6,900	9.1	11
Chromium	27	< 0.01	< 0.01
Copper	5,820	2.6	0.53
Mercury	180	< 0.02	< 0.02
Manganese	925	1.3	27
Nickel	-	< 0.05	0.08
Lead	143,500	5.5	4.5
Antimony	924	< 0.2	< 0.2
Zinc	79,900	7.5	9.5
Selenium	-	0.17	< 0.05
pH	-	6.8	6.7

2. Emissions Control Sludges. Sinter gases laden with SO_2 are partially scrubbed of particulates before entering the acid plant. Gases from other primary operations such as sinter crushing and blast furnacing are also cleaned in dry or wet scrubbers. The bulk of the dry dusts or wet slurries from gas cleaning operations are recycled to the sinter for lead recovery but a waste stream of 175 m^3/day containing 6 MT of solids is bled off. The solids generation rate from the gas cleaning bleed-off is 19 kg/MT of lead metal.

Sludges resulting from scrubbing of emissions from sintering and blast furnaces contain recoverable amounts of lead and zinc and significant concentrations of cadmium, copper and mercury. This waste stream is considered potentially hazardous.[1]

Present Individual Waste Handling Methods.

1. Acid Plant Blowdown and Miscellaneous Slurries. At the present time, blowdown slurries from the acid plant are treated with lime and sent to lagoons for settling. The miscellaneous slurries from plant washdown, the cadmium plant and other sources are sent to the same lagoon as the lime treated acid plant blowdown. The lagoon is dredged periodically and the sludge is piled on the ground to dry. At some plants this sludge is eventually recycled to the sinter while other plants may permanently dispose of the sludge on the ground. Long term storage on the ground or permanent land disposal may produce ground or surface water pollution either through percolation of leached toxic metals through permeable soils to ground water, or transport of toxic metal laden particulates by surface runoff. Soil and runoff conditions at individual smelters would determine the degree of potential hazard.

2. Emission Control Sludges. Dilute slurries resulting from control of emissions from sinters and blast furnaces are settled in unlined pits. The pits are dredged periodically and the sludge stored on land generally for months before recycle to the sinter plant for recovery. At some plants the sludge may not be recycled and is, therefore,permanently disposed of on land. usually in the slag dump. Long term on-land storage or permanent on-land disposal of emission control sludges can present the same environmental threat as the acid plant blowdown sludge.

Recommended Alternative Treatment Method for Combined Wastes. The sludges resulting from the (1) acid plant blowdown and miscellaneous slurries and (2) emission control sludges all contain recoverable amounts of lead and zinc. It is estimated that a typical plant producing 315 MT of lead per day will generate 3 MT of lead and 1.5 MT of zinc that is available for recovery.

A system enabling recovery and recycle of solids from the various sources is shown in Figure 14. Slurries from the acid plant and emission control would be lime treated and clarified in lined or impermeable lagoons. The settled solids would then be pumped to a storage tank. At this point, the solids content of the sludge will be 30%. From the storage tank, the sludge will be

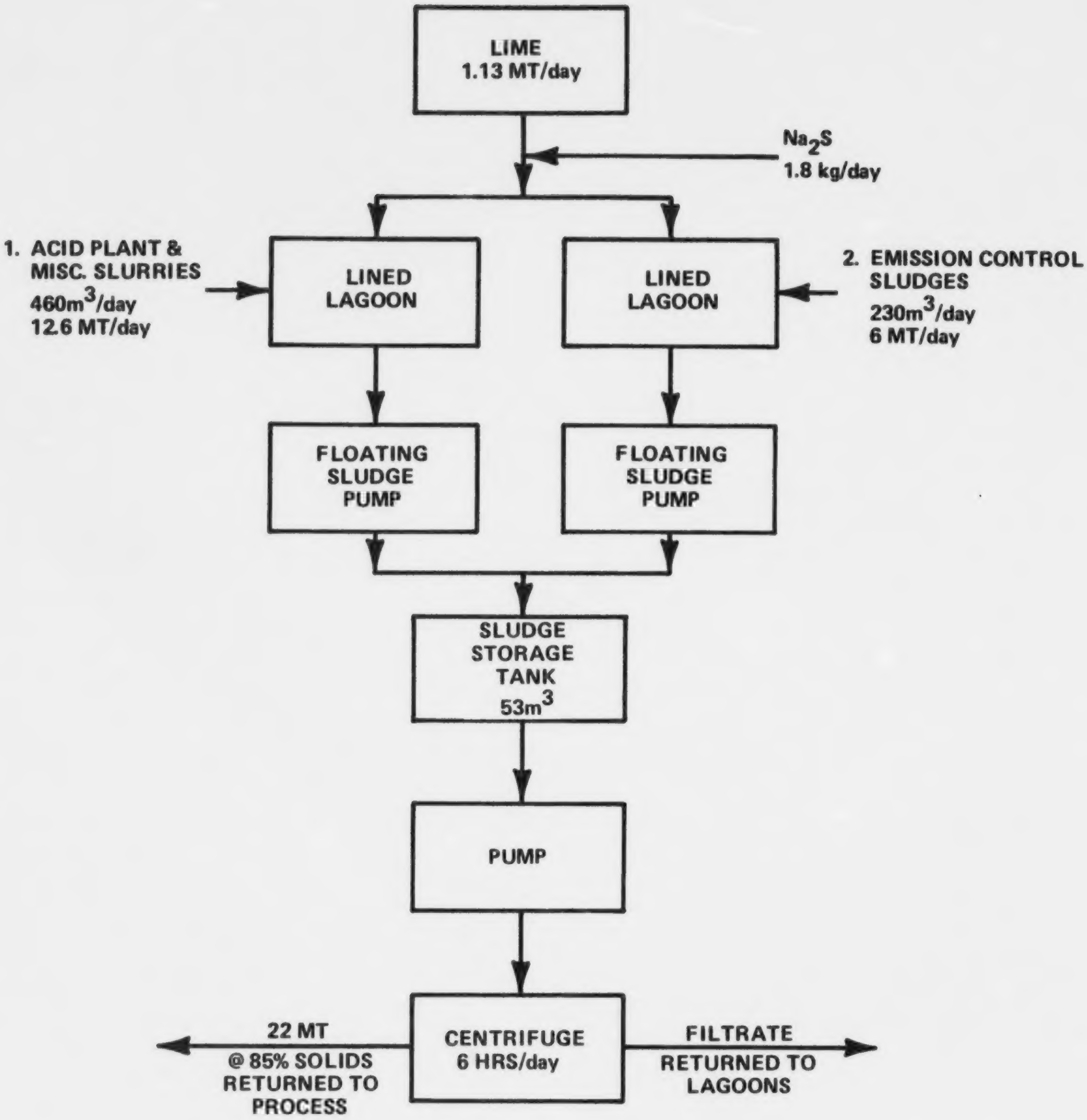
LIME
1.13 MT/day
Na_2S
1.8 kg/day
1. ACID PLANT & MISC. SLURRIES
460m^3/day
12.6 MT/day
LINED LAGOON
LINED LAGOON
2. EMISSION CONTROL SLUDGES
230m^3/day
6 MT/day
FLOATING SLUDGE PUMP
FLOATING SLUDGE PUMP
SLUDGE STORAGE TANK
53m^3
PUMP
22 MT
@ 85% SOLIDS
RETURNED TO PROCESS
CENTRIFUGE
6 HRS/day
FILTRATE
RETURNED TO LAGOONS

Figure 14. SCHEMATIC DIAGRAM FOR RECOVERY AND RECYCLE OF SLUDGE SOLIDS FROM PRIMARY LEAD SMELTER (WASTE STREAM NUMBER 17)

centrifuged to increase solids content to 85%. The solids amounting to 22 MT per day are recycled to the sinter. Filtrate from the centrifuge amounting to 53 m^3/day is sent back to the lagoons.

In order to insure complete precipitation of the heavy metals from the wastewaters, treatment with sodium sulfide in addition to the lime treatment is recommended. It is estimated that only 4 to 5 pounds (1.8 kg) of sodium sulfide per day would be sufficient to precipitate residual dissolved heavy metals as highly insoluble metallic sulfides. With proper retention in lagoons or settling basins, the combined lime-sodium sulfide treatment of acid plant blowdown, primary emission scrubwater, and miscellaneous slurries should result in highly purified effluent discharges to receiving waters.

The advantages to be derived from the proposed process are avoidance of potential contamination of ground and surface water with toxic heavy metals. In addition, resource recovery of up to 3 MT of lead and 1.5 MT of zinc per day is possible at the typical plant.

Cost of Alternative Method for Waste Handling. The cost for the flow scheme described in Figure 14 is summarized in Table 25.

A liner is installed in the acid plant blowdown lagoon. The lagoon inflow is treated with hydrated lime and sodium sulfide. Daily material usage consists of 1.13 metric tons (1.24 s. tons) of lime and 1.8 kg (4 lbs.) of sodium sulfide.

After settling, the sludge from the lagoon is pumped into a 53 m^3 (14,000 gal.) storage tank and then sent through a centrifuge. Twelve man-hours per day are assigned to the operation. Electrical energy use is based on an average consumption of 25 hp.

The centrifuge cake is returned to process; the filtrate flows to an existing lagoon. The centrifuge cake contains several metals, i.e., lead, cadmium, copper, antimony, and zinc. Its recovery value is based only on lead, which is present in the largest quantity. The value used is $154/metric ton ($140/s. ton) of contained lead. This cost represents about 25% of lead value.

Table 25
Capital and Annual Operating Costs for Alternative Treatment of Primary Lead Smelting Sludge (Waste Stream Number 17)

ANNUAL PRODUCTION (METRIC TONS): 110,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 6,500 **WET WEIGHT** 21,600

CAPITAL COST		
FACILITIES		
Lagoon Liners		$ 26,200
EQUIPMENT		
Lime Neutralization System	$32,000	
Sodium Sulfide Feed System	2,000	
Storage Tank	5,900	
Centrifuge	56,000	
Pumps	3,100	
Piping	2,200	
Installation	85,000	$186,200
CONTINGENCY		42,500
TOTAL CAPITAL INVESTMENT		254,900
ANNUAL COST		$ 41,550
AMORTIZATION		
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$56,700	
EQUIPMENT REPAIR AND MAINTENANCE	10,200	
MATERIALS	21,940	
WASTE DISPOSAL		
TAXES AND INSURANCE	10,200	$ 99,040
ENERGY		6,380
TOTAL ANNUAL COST		$146,970
RECOVERY VALUE		$168,780
NET ANNUAL COST		$ 21,810*

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS	1.01*	$ 6.80
DRY BASIS	3.36*	22.61
COST/METRIC TON OF PRODUCT	0.20*	1.34

* = Net gain from alternative treatment

SHORT TONS = 0.9 x METRIC TON

D. Electrolytic Zinc Manufacture - Sludge (Waste Stream Number 18)

Waste Description. In the production of zinc by the electrolytic process, zinc sulfide ore concentrates are first roasted to drive off sulfur as SO_2 and then leached with sulfuric acid to solubilize zinc. Impurities are precipitated from the zinc solution. The zinc is then plated electrolytically from the purified solution onto a cathode as pure zinc.

1. Miscellaneous Slurries. There are a number of miscellaneous acidic slurries associated with the electrolytic zinc purification process including scrubber bleeds, acid leach bleeds, anode washings, and spent electrolyte. A typical electrolytic zinc plant producing 285 MT of zinc per day will generate 1,500 m^3/day of miscellaneous wastewaters containing 2.6 MT per day of solids. The solids generation rate from the miscellaneous wastewaters is 9 kg/MT of zinc product.

2. Acid Plant Blowdown. Because a large volume of SO_2 is driven off by roasting the zinc sulfide ores, recovery of the SO_2 as sulfuric acid is practiced. The sulfuric acid in turn, is used to leach zinc from the roasted ore. The by-product sulfuric acid plant itself generates an acid blowdown slurry amounting to 1,380 m^3/day for the typical plant. The solids content of the blowdown slurry is 5 MT/day. The solids generation rate in the acid plant blowdown is 17 kg/MT of zinc metal produced.

The sludges which result from clarification of the (1) miscellaneous slurries and (2) acid plant wastewaters contain zinc and significant concentrations of cadmium, copper, and mercury. These sludges are considered potentially hazardous due to possible leaching of toxic heavy metal constituents. Analyses of the combined sludges are shown as follows :

Combined Sludges Analyses (ppm):[1]

Cadmium	820	Manganese	8,740
Chromium	44	Lead	15,300
Copper	2,510	Selenium	66
Mercury	22	Zinc	220,000

Present Waste Handling Method. 1. The miscellaneous wastewaters discussed previously are presently discharged to unlined lagoons for solids settling. Settled solids are dredged from the lagoon and dried on land prior to shipment to a lead smelter for recovery of zinc and lead value. The amount of wet sludge dredged per day amounts to 23 MT and contains 2.6 MT of solids.

2. Acid plant blowdown slurry is treated with lime for pH adjustment and heavy metal precipitation and then routed to an unlined lagoon for solids settling. The wet sludge is dredged from the lagoons and dried on land prior to shipment to a lead smelter for zinc and lead recovery. Approximately 5 MT of solids are contained in the wet sludges dredged each day.

Because the combined sludges are acidic, the leachate will contain soluble hazardous metals. The sludges are now settled in unlined lagoons. The settled solids are stored for some time before shipment to a lead smelter for recovery.

The use of unlined lagoons for settling and unprotected storage areas for these sludges present environmental pollution hazards if toxic heavy metal constituents of these sludges leach to the groundwater or are carried into surface waters. Soil and runoff conditions at individual plants would determine the degree of hazard.

Recommended Alternative Treatment Method. Recycle of acid plant sludge and the other miscellaneous sludges for metal recovery is practiced to a large extent by the industry. However, there are safeguards which can be incorporated into existing procedures to eliminate the potential for ground and surface water contamination, so that existing recycle practices can become environmentally sound. These include liming the entire wastewater discharge to effect maximum metal precipitation; the use of lined lagoons; and substituting a centrifuge for land storage to dewater sludges. These additional measures will eliminate ground and surface water pollution.

Figure 15 illustrates a modified electrolytic zinc plant sludge handling and processing system for eliminating potential water pollution. In this system, combined daily flow of 2,860 m^3/day from the acid plant blowdown and miscellaneous wastewaters are lime treated and clarified in a lined lagoon. An estimated 3 m^3/day of settled sludge will be pumped to a storage tank for dewatering in a centrifuge. Twenty percent solids sludge will be centrifuged to 85% solids. Sludge volume is reduced from 31 m^3/day to 3 m^3/day. The centrifuge cake containing 0.1 MT lead and 1.5 MT zinc/day would be stored in lined pits prior to shipment for lead and zinc recovery. The filtrate from the centrifuge amounting to 29 m^3/day would be recycled to the lagoon.

Cost for Alternative Treatment. The costs for the process scheme described in the block diagram of Figure 15 are summarized in Table 26 .

Plastic lagoon liners are installed in the two existing lagoons. The lagoon inflow is treated with hydrated lime at the rate of 1.9 metric tons (2.1 s. tons) per day. The settled sludge is pumped into an 18 m^3 (5,000 gal.) sump and then centrifuged.

Ten man-hours per day are assigned to the operation. Electrical energy use is based on an average consumption of 25 hp.

The centrifuge cake is stored for reprocessing and the filtrate returned to the existing lagoon. The centrifuge cake contains more zinc than any other precipitated heavy metal. Its value of $204/metric ton ($185/s. ton) of contained zinc represents 25% of zinc value.

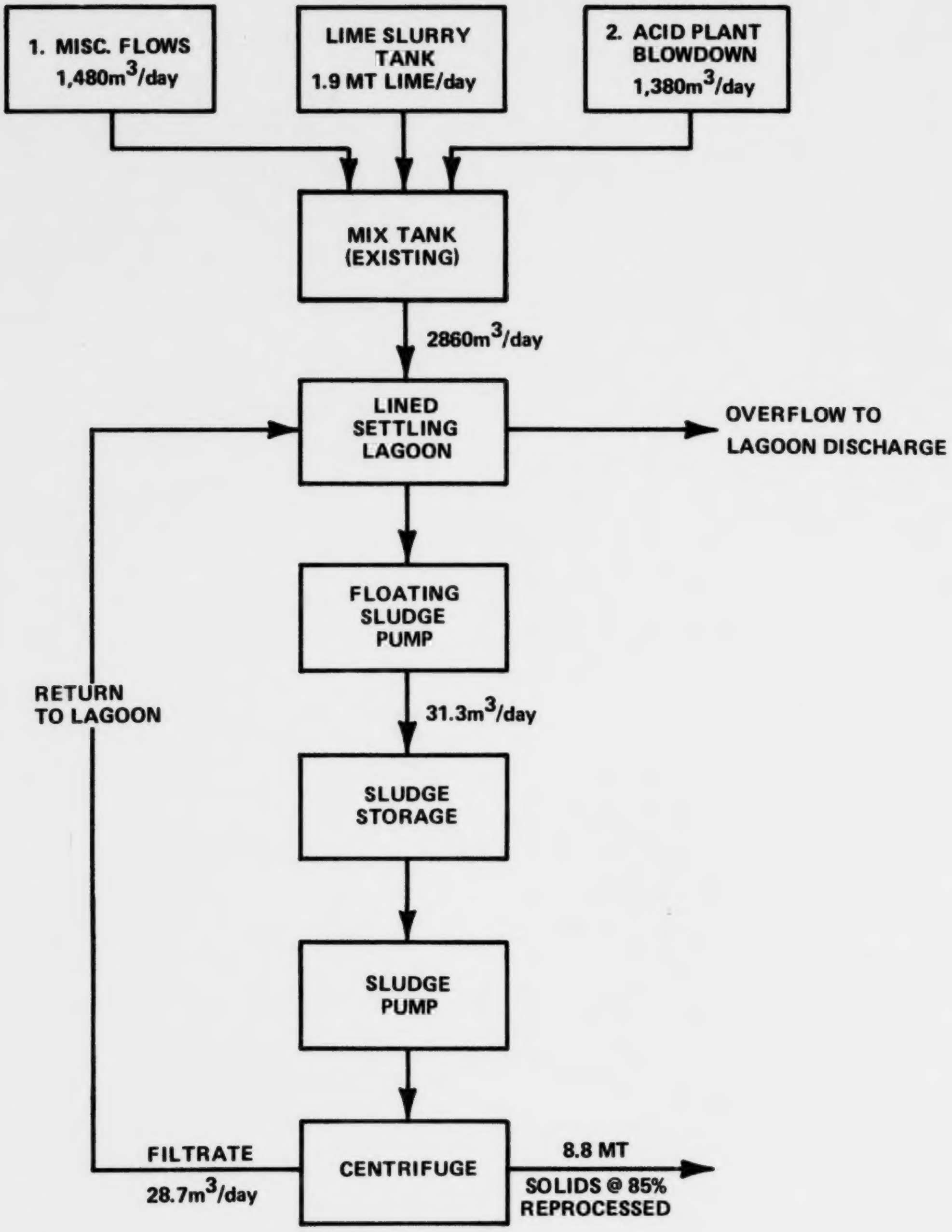
1. MISC. FLOWS
1,480m^3/day
LIME SLURRY TANK
1.9 MT LIME/day
2. ACID PLANT BLOWDOWN
1,380m^3/day
MIX TANK (EXISTING)
2860m^3/day
LINED SETTLING LAGOON
OVERFLOW TO LAGOON DISCHARGE
FLOATING SLUDGE PUMP
31.3m^3/day
SLUDGE STORAGE
SLUDGE PUMP
CENTRIFUGE
RETURN TO LAGOON
FILTRATE
28.7m^3/day
8.8 MT
SOLIDS @ 85%
REPROCESSED

Figure 15. SCHEMATIC DIAGRAM FOR RECOVERY AND RECYCLE OF ACID PLANT AND MISCELLANEOUS SLUDGES FROM ELECTROLYTIC ZINC PRODUCTION (WASTE STREAM NUMBER 18)

Table 26

Capital and Annual Operating Costs for Alternative Treatment of Sludge From Primary Electrolytic Zinc Manufacture (Waste Stream Number 18)

ANNUAL PRODUCTION (METRIC TONS): 100,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 2,600 **WET WEIGHT** 8,700

CAPITAL COST		
FACILITIES		
Lagoon Liners		$ 31,300
Sump		3,100
EQUIPMENT		
Lime Neutralization System	$33,000	
Centrifuge	48,000	
Pumps	3,600	
Piping	600	
Installation	72,600	157,800
CONTINGENCY		$ 38,400
TOTAL CAPITAL INVESTMENT		230,600
ANNUAL COST		
AMORTIZATION		$ 37,590
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$47,250	
EQUIPMENT REPAIR AND MAINTENANCE	9,220	
MATERIALS	36,580	
WASTE DISPOSAL		
TAXES AND INSURANCE	9,220	$102,270
ENERGY		6,380
TOTAL ANNUAL COST		$146,240
RECOVERY VALUE		$117,100
NET ANNUAL COST		29,140*

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS	$ 3.50 *	$16.81
DRY BASIS	11.20 *	56.25
COST/METRIC TON OF PRODUCT	0.29 *	1.46

* = Net gain from alternative treatment

SHORT TONS = 0.9 x METRIC TON

E. Pyrometallurgical Zinc Manufacture - Sludges
(Waste Stream Number 19)

Waste Description. In the production of zinc metal by the pyrometallurgical process, zinc sulfide ore concentrates are roasted to drive off sulfur as SO_2 gas and to volatilize metal impurities such as cadmium and lead. The roasted material is then agglomerated in a sintering operation and fed to heated retorts where the addition of coke reduces zinc oxides and other zinc compounds to volatilized zinc metal. The volatilized zinc is then condensed as zinc metal. The condensed zinc metal may be redistilled for further purification or oxidized to produce zinc oxide by the French process.

Secondary operations include recovery of cadmium from sinter and roasting fumes, production of lead oxide by the American process, and production of sulfuric acid from the SO_2 contained in the roaster gases.

1. Slurries from Primary Gas Cleaning and Acid Plant Blowdown. Particulates are removed from SO_2 laden gases in baghouses and wet or dry electrostatic precipitators before entering the acid plant. Gases from other primary operations such as sintering and crushing are similarly cleaned. Most of the dusts and slurries resulting from gas cleaning are recycled immediately but a portion of the slurries amounting to 93 kg/MT zinc is bled off, limed and thickened in conjunction with acid plant blowdown. For the typical plant producing 310 MT of zinc per day, gas cleaning slurries may total 1,090 m^3/day and contain 29 MT of solids.

The typical plant generating sulfuric acid from SO_2 roaster gases, generates 1,310 m^3 of blowdown per day containing 9 MT of solids. The solids generation rate is 90 kg/MT of zinc product. Both the acid plant blowdown and the gas cleaning slurries are combined and processed in a lime treatment system. The sludge resulting from the combined treatment of acid plant blowdown and primary gas scrubbing contain recoverable amounts of zinc and significant concentrations of cadmium, copper, lead, and mercury which are considered potentially hazardous.[1]

2. Retort Gas Scrubber Bleed ("Blue Powder"). A small portion of the volatilized zinc laden gases produced in the retorting operations passes through the zinc condensers and is recovered as "blue powder" from wet scrubber bleeds. The daily volume of wet scrubber bleed is 5 m^3 and contains 3 MT of solids. Solids generation rate of blue powder is 10 kg/MT of zinc product.[1]

Sludge analyses are shown as follows:

Analysis of Gas Cleaning and Acid Plant Blowdown Sludges (ppm):

Cadmium	822	Selenium	46
Chromium	31	Zinc	306,900
Copper	540	Mercury	9
Lead	2,920		

Present Waste Handling Methods.

1. Primary Gas Cleaning and Acid Plant Blowdown Sludges. At the present time, dilute slurries from the primary gas cleaning operations and from the acid plant blowdown are jointly treated in a lime treatment system and sent to unlined lagoons for settling. The settled lime sludges containing 122 kg of dry solids per metric ton of zinc are periodically dredged from lagoons and either stored on land for several months before recycling or permanently deposited on land.

The use of unlined lagoons for clarification and open dumps for sludge storage or disposal may pose an environmental threat if potentially hazardous metal constituents including cadmium, mercury, zinc, and lead percolate through permeable soils to groundwater or are carried into surface streams with runoff.

2. Retort Gas Scrubber Bleed ("Blue Powder"). At the present time, scrubber bleed water from retort emissions control is clarified in a lagoon which is periodically dredged. The dredged material (10 kg/MT zinc, dry weight) is also often recycled after several months storage on land or may be permanently disposed of on land.

Storage or permanent disposal of retort scrubber sludge poses a threat to groundwater or surface water quality under the conditions described for gas cleaning and blowdown sludges.

Recommended Alternative Treatment Method.

1. Primary Gas Cleaning and Acid Plant Blowdown Sludges. The sludges resulting from lime treatment of gas cleaning scrubwater and acid plant blowdown contain an estimated 30% zinc by dry weight and can be recycled for zinc recovery. Approximately 11 MT of zinc per day is available for recovery from these sludges.

Figure 16 depicts an environmentally sound system for effecting immediate recycle of sludge solids to the process rather than short term or permanent storage on the ground.

In this system, combined wastewater flow from the acid plant blowdown and emissions scrubber water totalling about 2,396 m^3/day is sent to a thickener. Underflow from the thickener amounting to 83 m^3/day is centrifuged for dewatering. Overflow from the thickener amounting to 2,313 m^3/day is sent to a polishing clarifier and its underflow amounting to 71 m^3/day is also centrifuged.

Overflow from the clarifier and filtrate from the centrifuge amounting to 2,360 m^3/day would be stored in a lagoon and should be suitable for reuse in the emissions control systems for the roaster, sinter, and retort.

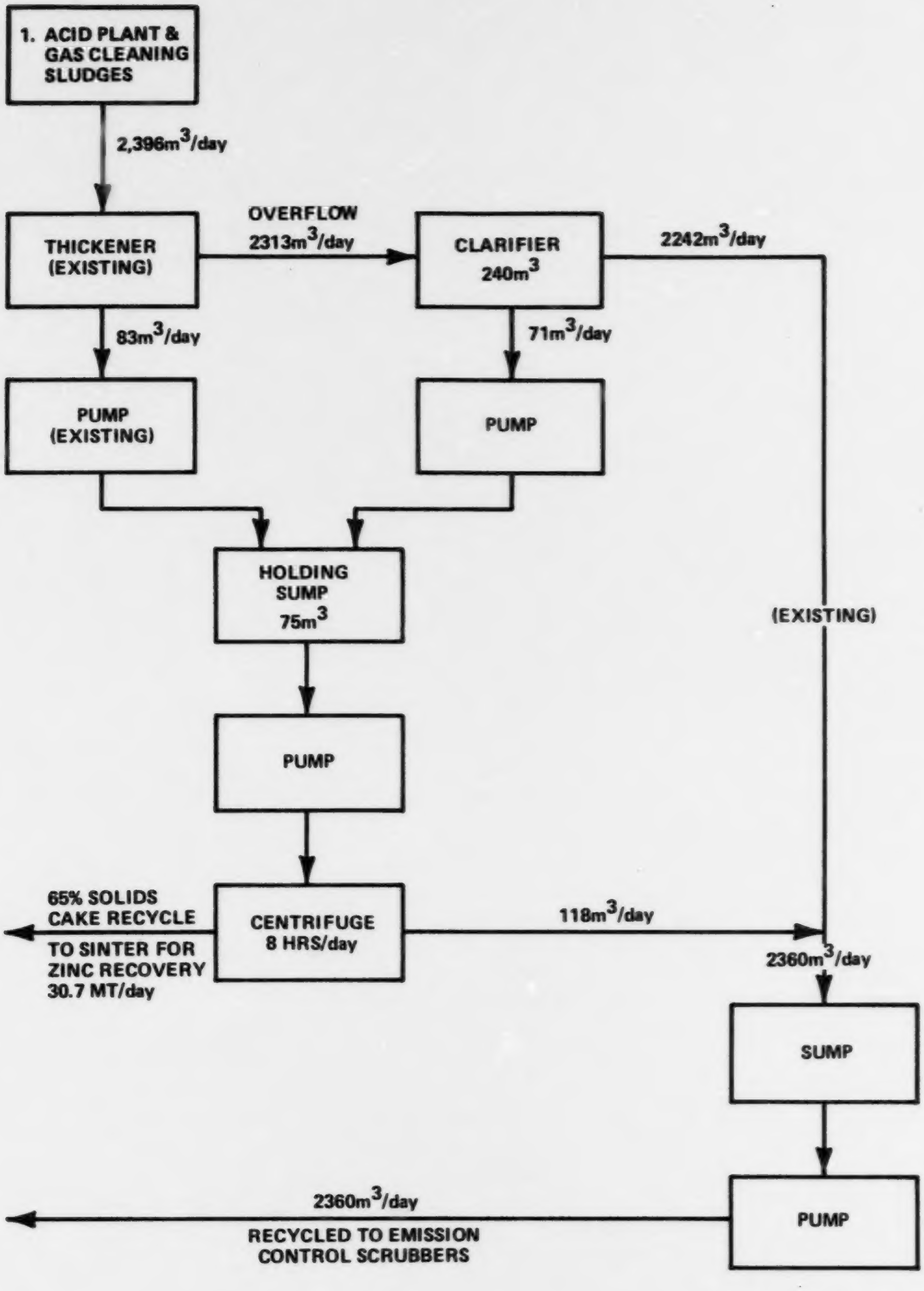
1. ACID PLANT & GAS CLEANING SLUDGES
2,396m³/day
THICKENER (EXISTING)
OVERFLOW 2313m³/day
CLARIFIER 240m³
2242m³/day
83m³/day
71m³/day
PUMP (EXISTING)
PUMP
HOLDING SUMP 75m³
(EXISTING)
PUMP
65% SOLIDS CAKE RECYCLE
TO SINTER FOR ZINC RECOVERY 30.7 MT/day
CENTRIFUGE 8 HRS/day
118m³/day
2360m³/day
SUMP
2360m³/day
PUMP
RECYCLED TO EMISSION CONTROL SCRUBBERS

Figure 16. SCHEMATIC FLOW FOR RECYCLE OF SLUDGES FROM PRIMARY PYROMETALLURGICAL ZINC ACID PLANT AND GAS CLEANING SLUDGES (WASTE STREAM NUMBER 19)

2. Retort Gas Scrubber Bleed Sludge ("Blue Powder"). The sludge solids from the retort scrubber bleed water is very high in zinc content which should be reclaimed. An environmentally sound system for immediate recycle of retort scrubber sludge rather than long term storage or disposal of this sludge on the ground is shown in Figure 17.

In this system, the 5 m^3 of retort scrubber bleed is processed through a centrifuge for concentration of solids to 95%. These solids amount to 3.2 MT per day and occupy 0.5 m^3. The retort scrubber bleed solids would either be recycled immediately to the process or temporarily stored in a concrete pit prior to recycle.

Filtrate from the centrifuge amounting to 4.5 m^3 per day will be recycled as scrubwater.

Cost of Recommended Alternative Treatment. The costs for the alternative treatment system described in Figure 16 on primary gas cleaning and acid plant blowdown sludges is summarized in Table 27 .

The overflow from an existing thickener is directed to a 240 m^3 (30 ft diameter) clarifier. The underflow from the thickener and the clarifier is pumped to a 75 m^3 (20,000 gal) sump and then centrifuged. Eight man-hours per day are assigned to the operation.

The centrifuge cake is put into bins and reprocessed in the zinc smelter. The cost of transporting this waste is included at $1/metric ton ($0.90/s. ton). The filtrate is returned to an existing lagoon.

The value of the recovered material is computed on the basis of contained zinc at $204/metric ton ($185/s. ton).

The costs for the improved method of handling sludges from retort gas scrubber bleed schematically described in Figure 17 are summarized in Table 28 .

The sludge is pumped to a sump and then centrifuged. The system is operated 8 hours/day and 4 man-hours are estimated to be required.

The inclusion of a centrifuge is the only difference between the proposed treatment system and existing operations. The zinc dust (blue powder) is presently being recycled; therefore, no value is assigned to the recovered material.

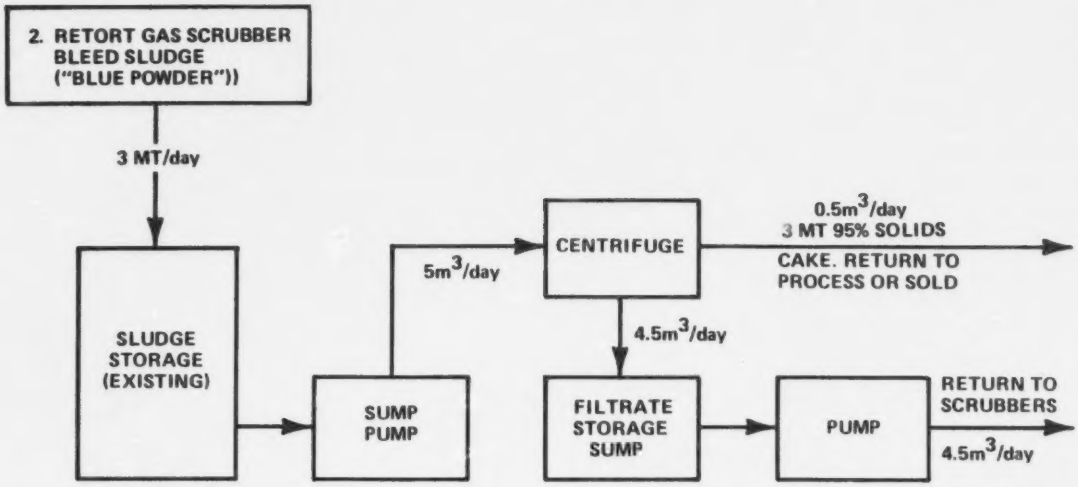
2. RETORT GAS SCRUBBER BLEED SLUDGE ("BLUE POWDER"))
3 MT/day
SLUDGE STORAGE (EXISTING)
SUMP PUMP
5m³/day
CENTRIFUGE
0.5m³/day
3 MT 95% SOLIDS
CAKE. RETURN TO PROCESS OR SOLD
4.5m³/day
FILTRATE STORAGE SUMP
PUMP
RETURN TO SCRUBBERS
4.5m³/day

Figure 17. SCHEMATIC FLOW FOR RECYCLE OF SLUDGE FROM RETORT SCRUBBER BLEED. PRIMARY PYROMETALLURGICAL ZINC. (WASTE STREAM NUMBER 19)

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TABLE 27

Capital and Annual Operating Costs for Alternative Treatment of Sludge from (1) Primary Gas Cleaning and Acid Plant Blowdown in Pyrometallurgical Zinc Manufacture (Waste Stream Number 19)

ANNUAL PRODUCTION (METRIC TONS): 107,000

ANNUAL WASTE (METRIC TONS): DRY WEIGHT 13,000 WET WEIGHT 43,000

CAPITAL COST		
FACILITIES		
Sump		$ 7,700
EQUIPMENT		
Clarifier	$ 45,000	
Centrifuge	100,000	
Sludge Bins (2)	10,000	
Pumps	1,700	
Piping	1,300	
Installation	144,200	302,200
CONTINGENCY		62,000
TOTAL CAPITAL INVESTMENT		$371,900
ANNUAL COST		
AMORTIZATION		$ 60,620
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$37,800	
EQUIPMENT REPAIR AND MAINTENANCE	14,880	
MATERIALS		
WASTE TRANSPORT	20,300	
TAXES AND INSURANCE	14,880	$ 87,860
ENERGY		4,700
TOTAL ANNUAL COST		$153,180
RECOVERY VALUE		817,220
NET ANNUAL COST		$ 664,040

COST/METRIC TON OF WASTE	NET	TOTAL
WET BASIS	$ 15.44*	$ 3.56
DRY BASIS	51.08*	11.78
COST/METRIC TON OF PRODUCT	6.21*	1.43

* = Net gain from alternative treatment

SHORT TONS = 0.9 x METRIC TON

TABLE 28

Capital and Annual Operating Costs for Alternative Treatment of Sludge From (2) Retort Gas Scrubber Bleed in Pyrometallurgical Zinc Manufacture
(Waste Stream Number 19)

ANNUAL PRODUCTION (METRIC TONS): 107,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 1,100 **WET WEIGHT** 2,200

CAPITAL COST		
FACILITIES		
Sump		$ 300
EQUIPMENT		
Centrifuge	$25,000	
Valves	100	
Pumps	1,400	
Piping	400	
Installation	20,300	$47,200
CONTINGENCY		9,500
TOTAL CAPITAL INVESTMENT		$57,000
ANNUAL COST		
AMORTIZATION		$ 9,290
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$18,900	
EQUIPMENT REPAIR AND MAINTENANCE	2,280	
MATERIALS		
WASTE DISPOSAL		
TAXES AND INSURANCE	2,280	$23,460
ENERGY		900
TOTAL ANNUAL COST		$33,650
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS		$15.30
DRY BASIS		30.59
COST/METRIC TON OF PRODUCT		0.31

SHORT TONS = 0.9 x METRIC TON

F. Aluminum Manufacture

1. Spent Potliners and Skimmings (Waste Stream Number 21)

Waste Description. Metallic aluminum is produced by the electrolytic dissociation of alumina (Al_2O_3) dissolved in a molten bath of cryolyte (Na_3AlF_6), aluminum fluoride (AlF_3), and calcium fluoride (CaF_2). The bath, or electrolyte, is contained in a carbon-lined shell which serves as the cathode. The free molten metallic aluminum collects at the bottom of the cathode or pot and is tapped off periodically as required. During operation of the cells, bath materials gradually adhere onto the cathode liners and the weight of the liners may nearly double before replacement. These "spent potliners" are a major source of waste material in primary aluminum plants. Another source of waste from cell operations is the "pot skimmings" derived from the removal of crust buildup on the surface of the molten bath.

Since new potliners are made of carbon, and since the weight of a potliner approximately doubles over its lifetime resulting from accumulated bath materials, the composition of the spent potliners is 50 percent carbon or more. The remainder is mostly aluminum, fluorine, and sodium. Traces of cyanide are also present.

Typical analyses and solubility test filtrate analyses[1,7] are shown as follows:

Typical Analyses (%):

Fluorine	12.5	
Aluminum	13.9	
Carbon	23.5	13-60
Sodium	14.3	

Solubility Test Filtrate Analyses (ppm):

Fluorine	10,400
Cyanide	5,460
pH	12.6

Currently these wastes are stored on land, some of which is sold for cryolite recovery. Some plants recover their own cryolite.

The major constituents of pot skimmings are aluminum (17-20%), fluorine (34-38%), carbon (11-14%), and sodium (19-20%).[5,6,7]

The amounts of spent potliners and pot skimmings generated per unit of aluminum produced vary from plant to plant. The generation factor can range from 38 to 60 kg/MT aluminum produced with a typical value of approximately

53 kg/MT for spent potliners. The average generation factor for pot skimmings is about 5.5 kg/MT of aluminum. A typical primary aluminum plant with an annual production of 153,000 metric tons of aluminum would generate 7,344 MT of spent potliners and 842 MT of pot skimmings.

Present Methods for Handling Waste. Spent potliners and pot skimmings contain valuable materials and, therefore, are either stored, sold or processed for recovery of cryolite. Some of the larger primary aluminum plants have cryolite recovery facilities that handle spent potliners and pot skimmings from other plants as well as their own. Plants that do not have a reprocessing operation store the wastes on site for periods ranging from weeks to years depending, in part, on the proximity of a reprocessing plant. Different cryolite recovery systems produce different grades of cryolite and not all primary aluminum plants will accept the lower grades of cryolite. Some of the cryolite recycle systems process scrubber water from potline emissions control systems, in addition to spent potliners and pot skimmings.

Currently, the trend in the industry is toward dry systems for controlling potline emissions. Some of these systems use alumina as a medium for adsorbing fluorides contained in the cell emissions. The spent alumina, along with the adsorbed fluorides is introduced into the cells as feed material. Plants using dry emission controls require a higher ratio of aluminum fluoride to cryolite cell feed than those using wet controls. The "dry-plants" can use only 40 to 50 percent of the cryolite that can be recovered from their own spent potliners. The technology for recovering aluminum fluoride from spent potliners, when developed, would achieve a recovery ratio of aluminum fluoride to cryolite more favorable to the material requirements of these plants and would make reprocessing of all spent potliners feasible. Thus, plants using dry potline emission control systems do not need all of the recoverable cryolite and cannot process all the spent potliners. The unprocessed potliners are stored in anticipation of future technology that will make the recovery of aluminum fluoride economically feasible.

Some aluminum plants that store spent potliners, either temporarily before shipping to another plant for cryolite recovery, or for longer periods, do not control precipitation runoff from the storage piles. In other plants, the storage area is lined and trenched. The water collected in the trenches is treated with other plant wastewaters such as potline scrubber water. Reference 1 describes the potential hazards to the environment resulting from present methods for handling and disposal of these wastes.

Solubility tests on spent potliner samples indicate that fluorides and cyanide can be leached from these wastes quite readily.[1] Therefore, long term storage of spent potliners in large open piles presents a potential hazard unless adequate control of precipitation runoff is provided. If the potliners are processed for cryolite recovery, then only small storage piles are required and control of runoff water is easier to implement.

Recommended Alternative Treatment Method. In existing systems for processing spent potliners to recover standard grade cryolite, the potliners are crushed and reacted with caustic to produce soluble sodium aluminate ($Na_2Al_2O_4$) and sodium fluoride (NaF).[6] The resulting slurry is washed in a mud wash thickener to recover entrained fluoride. Sodium fluoride derived from treatment of the potline scrubber water is added to the liquor from the thickener to provide a stoichiometric ratio of sodium and fluoride, corresponding to that found in the cryolite. The liquor is then acidified by reacting with carbon dioxide causing the cryolite to precipitate from a sodium carbonate solution. The cryolite is separated from the sodium carbonate spent liquor by a filter and dried. The cryolite obtained by this process is 90 percent pure. This grade of cryolite can be used in most primary aluminum plants. Its use is limited only when very high grade aluminum is being produced. The process is described schematically in Figure 18.

The value of the materials contained in the spent potliners and pot skimmings and the large volumes of these residuals that are generated, make recycling of these wastes highly desirable. However, the economics are not always favorable depending on the grade and type of recovered material required and the size of the plant.

Of the more than 30 aluminum smelting plants operating in the United States, probably no more than 20 percent have on-site facilities for processing spent potliners for material recovery.

At least two plants operate systems for recovering standard grade cryolite from spent potliners and other fluoride-bearing materials that are a by-product of primary aluminum production. Two plants, located at Longview, Washington and Sheffield, Alabama, are owned by Reynolds Metals Company. These two plants process spent potliners from other Reynolds' plants, as well as their own.

The benefits derived from processing spent potliners and other materials generated by primary aluminum smelters include a major reduction in the volume of fluoride-bearing materials that require storage and/or disposal and a reduction in the amounts of virgin raw materials required. In addition, some energy recovery might be possible in low grade cryolite recovery systems during the roasting operation.

Cost for Cryolite Recovery System. The costs for a cryolite recovery system as described by Figure 18 are summarized in Table 29. The spent potliners and skimmings discussed in this part of the report will be treated in the same cryolite recovery plant as the scrubber sludges to be discussed in the following part of this report.

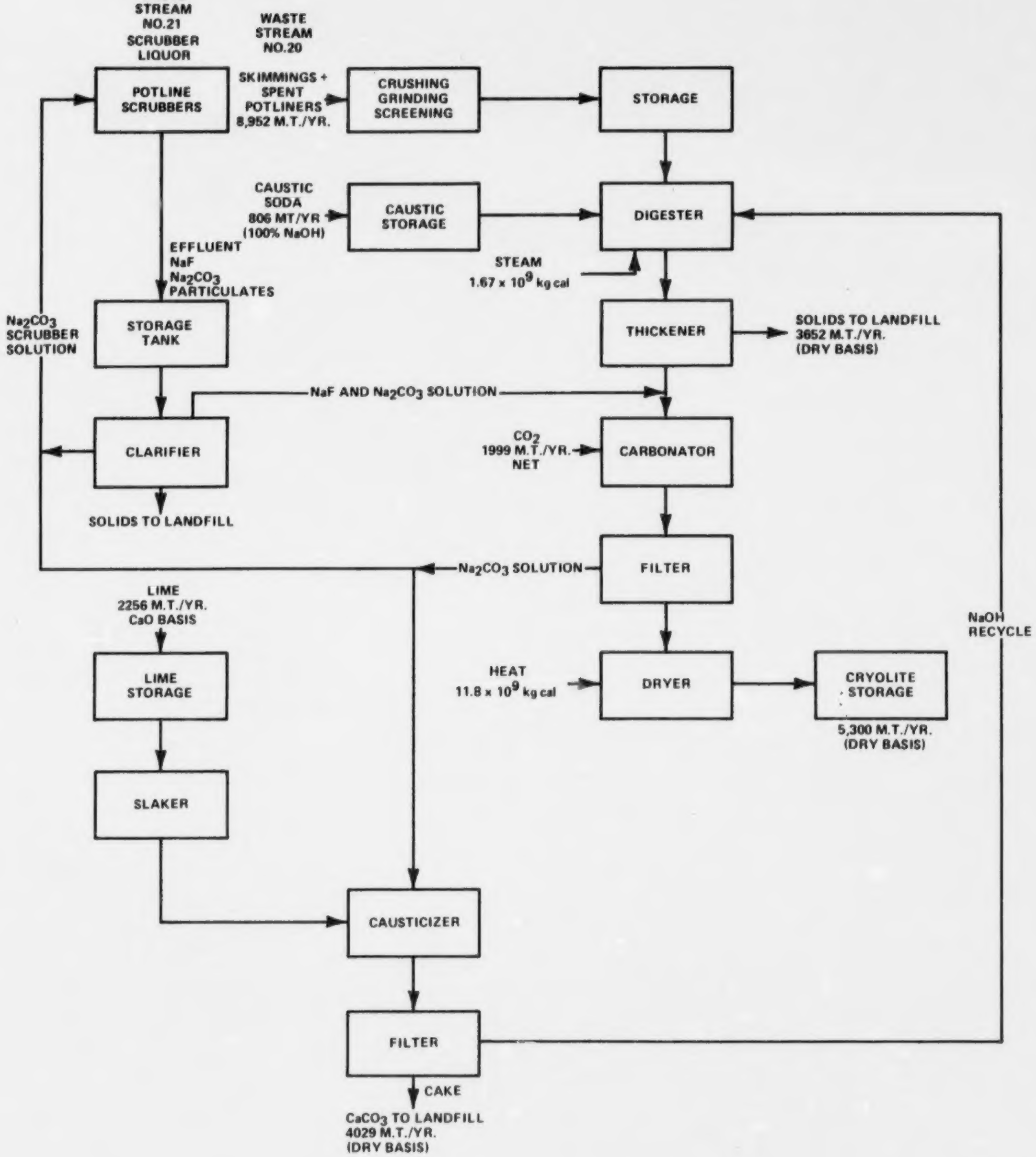
WASTE STREAM NO.21 SCRUBBER LIQUOR
WASTE STREAM NO.20
POTLINE SCRUBBERS
SKIMMINGS + SPENT POTLINERS 8,952 M.T./YR.
CRUSHING GRINDING SCREENING
STORAGE
CAUSTIC SODA 806 MT/YR (100% NaOH)
CAUSTIC STORAGE
DIGESTER
EFFLUENT NaF Na_2CO_3 PARTICULATES
STEAM 1.67×10^9 kg cal
Na_2CO_3 SCRUBBER SOLUTION
STORAGE TANK
THICKENER
SOLIDS TO LANDFILL 3652 M.T./YR. (DRY BASIS)
NaF AND Na_2CO_3 SOLUTION
CO_2 1999 M.T./YR. NET
CLARIFIER
CARBONATOR
SOLIDS TO LANDFILL
Na_2CO_3 SOLUTION
FILTER
LIME 2256 M.T./YR. CaO BASIS
NaOH RECYCLE
LIME STORAGE
HEAT 11.8×10^9 kg cal
DRYER
CRYOLITE STORAGE
5,300 M.T./YR. (DRY BASIS)
SLAKER
CAUSTICIZER
FILTER
CAKE
$CaCO_3$ TO LANDFILL 4029 M.T./YR. (DRY BASIS)

Figure 18. FLOW DIAGRAM FOR STANDARD GRADE CYROLITE RECOVERY FROM SPENT POTLINERS, POT SKIMMINGS, AND POTLINE SCRUBBER SLUDGES (WASTE STREAMS NUMBERS 20 AND 21)

TABLE 29

Capital and Annual Operating Costs for Cryolite Recovery Alternative Treatment of Potliners, Pot Skimmings and Potline Scrubber Sludges in Primary Aluminum Manufacture (Waste Stream Numbers 20 and 21)

ANNUAL PRODUCTION (METRIC TONS): 153,000

ANNUAL WASTE (METRIC TONS): DRY WEIGHT 26,900 **WET WEIGHT** 59,500

CAPITAL COST		
FACILITIES		$1,790,000
EQUIPMENT		
Installed Equipment		1,790,000
CONTINGENCY		716,000
TOTAL CAPITAL INVESTMENT		$4,296,000
ANNUAL COST		
AMORTIZATION		$ 700,250
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$453,600	
EQUIPMENT REPAIR AND MAINTENANCE	171,840	
MATERIALS	283,910	
WASTE DISPOSAL	173,780	
TAXES AND INSURANCE	171,840	$1,254,970
ENERGY		132,920
TOTAL ANNUAL COST		$2,088,140
RECOVERY VALUE		3,180,000
NET ANNUAL COST		$ 1,091,860*

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS	$18.35*	$35.09
DRY BASIS	$40.59*	$77.63
COST/METRIC TON OF PRODUCT	7.14*	13.65

* = Net gain from alternative treatment

SHORT TONS = 0.9 x METRIC TON

The cryolite recovery process is designed to recover 5,300 metric tons (5,830 s. tons) of cryolite from the waste potliners, pot skimmings and potline scrubber sludges. Implementation of the process requires the construction of a separate facility.

The capital costs shown in Table 29 are based on estimates of the personnel, material, energy and waste disposal requirements from which the annual costs are computed.

This represents a new facility and a high degree of uncertainty is associated with the capital cost estimate. It is assumed here that facility costs will equal the cost of installed equipment.

Operating labor consists of four men per shift, i.e., 96 man-hours per day. Annual material requirements are 806 metric tons (887 s. tons) of caustic soda, 2257 metric tons (2783 s. tons) of pebble lime and 22,647 m^3 (6 x 10^6)of process water.

Annual energy requirements include fuel for the dryer and carbonator (46.8 x 10^9 Btu's), steam for the digester (6.6 x 10^6 Btu's) and electricity (50 hp) for other operating equipment.

Approximately 11,600 m^3 (15,000 yd^3) of waste are sent to a chemical landfill annually.

The process results in an annual recovery of 5,300 metric tons (5,830 s. tons) of standard grade cryolite valued at $600 per metric ton ($545/s. ton).

F. Aluminum Manufacture

2. Scrubber Sludges
(Waste Stream Number 20)

Waste Description. Many primary aluminum plants use wet scrubber systems for controlling emissions from the electrolytic cells. In a number of plants the scrubber liquor is treated with lime and passed through a clarifier. The underflow from the clarifier is then discharged to a sludge lagoon. In some instances, the clarifier is eliminated and the lime-treated liquor is piped directly to a lagoon where the solids settle as a sludge. The average amount of sludge accumulated on a dry-weight basis is 113 kg/MT of aluminum produced. For a typical plant, this amounts to approximately 17,000 MT/yr. The scrubber water used to control emissions from anode bake plants is usually treated together with the potline scrubber water. The anode bake plant and potline scrubber system generates 3.7 kg of sludge per metric ton of aluminum produced. The total weight of sludge generated depends to a significant degree on the amount of lime added to the scrubber water. The values given correspond to lime addition in amounts from 1 to 2 times the stoichiometric requirement; higher treatment ratios are sometimes used.

The sludge from the potline and bake plant scrubbers contains fluorine, aluminum, carbon and sodium as major constituents, with fluorine accounting for up to about 20 percent of the average sludge weight.[5]

Typical analyses of scrubber sludges and solubility test filtrate analyses are summarized as follows:

Typical Analyses[5] (%)

Fluorine	23.7
Aluminum	13.8
Carbon	31.7
Sodium	12.5

Solubility Test Filtrate Analyses[1] (ppm)

Fluorine	8.0

In some primary aluminum plants, the scrubber liquor is processed to recover the fluoride values as a low-grade cryolite. In some instances, this is done in conjunction with the processing of spent potliners for cryolite recovery.

Present Methods for Handling Waste. The sludges generated by lime treatment of the scrubber liquor from potlines and anode bake plants accumulate in lagoons as noted previously. Usually, the lagoons are dredged periodically at a frequency that depends on the size of the plant, the level of treatment,

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and the volume of the lagoon. The dredged material is commonly deposited on open land near the lagoons. Alternatively, a new lagoon might be constructed and the old lagoon phased out as the volume of accumulated sludge becomes excessive. Successful methods have not been developed for recovering useful materials from the sludges generated by lime treatment of potline emissions scrubber water.

About half of the plants that have wet-type scrubbers for control of potline emissions have some provision for recovering cryolite from the scrubber liquor. In some cases, the recovery system is capable of processing spent potliners, as well as scrubber liquor. A brief description of the method for recovering cryolite from fluoride-bearing residues was given in the previous section on spent potliners.

Recommended Alternative Treatment Method. Recovery of cryolite from scrubber liquor, as an alternative to lime treatment and settling, has the advantage of allowing resource recovery and reducing waste volumes. However, cryolite recovery becomes advantageous, for appropriate production capacities and the purity of aluminum being produced.

A system commonly used for processing potline scrubber liquor and spent potliners for the recovery of standard grade cryolite is described in the previous section covering spent potliners and is shown schematically in Figure 18.

At least two plants operate systems for recovering standard grade cryolite as noted in the discussion for spent potliner wastes. The two plants, located at Longview, Washington and Sheffield, Alabama, are owned by Reynolds Metals Company.

The advantage of processing potline scrubber water for recovery of cryolite, as opposed to adding lime to precipitate solids in a clarifier and/or lagoon is that it allows a valuable material to be recovered, thereby reducing virgin raw material requirements, and at the same time reduces the amount of fluoride-bearing waste material destined for land disposal.

Cryolite recovery from potline emission scrubber liquor reduces the amounts of potentially hazardous wastes that must be land disposed, thereby reducing the probability of adverse environmental effects caused by leaching. In addition, because cryolite recovery reduces the amounts of virgin raw materials required, the environmental impacts resulting from raw materials acquisition, processing and transport are reduced accordingly and significantly.

F. Aluminum Manufacture

3. Shot Blast and Cast House Dusts
(Waste Stream Number 22)

Waste Description. The prebaked carbon anodes used in aluminum reduction cells must be replaced periodically. A metal rod extending from the center of the carbon anodes serves to connect the anode electrically to the anode bus. When the spent anodes are removed from service, the carbon is broken off and the metal rods are saved for reuse. The rods which are copper with steel ends are cleaned by shot blasting and then reused. The dust collected in the shot blast cleaning of the anode rods is a dust residue that must be disposed of.

Molten aluminum tapped from the reduction cells is transferred to the cast house where it is alloyed with other metals and cast into ingots. The skim removed from the molten metal amounts to about two percent of the total metal poured and contains about 50 percent aluminum and 50 percent oxides. The skim is processed to recover 15 to 40 percent of the aluminum. The residual material is frequently sold to secondary aluminum smelters for further reclamation of aluminum values. One type of skim processing consists of a rotating barrel which may be heated to prevent the skim from freezing. The rotation causes the metal to coagulate. Periodically, the rotation is stopped and the metal is drained from the bottom through a tap hole. The dust emitted in the skim processing operating is sometimes collected in a cyclone-type system for land disposal.

The shot blast dusts which are mostly iron and carbon also contain 2-3% fluorine and 1-2% copper concentrations. The cast house dust is primarily aluminum and oxides with small amounts of other metals such as copper and lead, depending on the type of alloy cast. Analytical data are shown as follows:

Typical Analyses (ppm)[1]

	Shot Blast Dust	Cast House Dust
Fluorine	28,000	-
Copper	15,000	6,200
Lead	-	4,600

Solubility Test Filtrate Analyses (mg/1)[1]
Shot Blast Dust

Copper	0.14	Manganese	20
Zinc	0.2	Nickel	0.13
Lead	< 0.02	pH	7.4
Chromium	< 0.02		

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The dry dusts from shot blasting anode rods and the processing of cast house skim total approximately 7.5 kg/MT of aluminum produced. Shot blast dust accounts for two-thirds of the total amount or 5 kg/MT. A typical plant producing 153,000 MT of aluminum annually would generate 765 MT of shot blast dust and 383 MT of cast house dust per year.

Present Methods for Waste Disposal. The shot blasting and skim processing dusts are commonly disposed of on land, in open piles or in a landfill. It is believed that all such wastes are handled in this manner and that special methods are not used for resource recovery or for treatment prior to disposal.

Tests performed on shot blast dust and cast house dust indicate a potential for leaching fluorine, copper, lead, zinc, nickel, and manganese from these wastes if they are dumped on land without precautionary treatment.[1] Analytical data are shown above.

Recommended Alternative Treatment Method. The quantity and concentration of recoverable materials are relatively low and do not presently offer recovery potential. In order to prevent leaching of potentially hazardous constituents from shot blast and cast house dusts, an alternative to simple land dumping or landfill is the treatment of these wastes with hydrated lime prior to disposal in a chemical landfill. One means of providing such treatment is to transfer the two waste materials to a storage bin and feed them at a fixed rate to a screw conveyor. Just downstream of where the dusts are added, hydrated lime and water would also be added. The wetted mixture leaving the screw conveyor would then be transferred to a chemical landfill.

This method of handling shot blast dusts and cast house dusts is not commonly practiced but is designed to minimize the leaching and subsequent movement of potentially hazardous constituents into ground water or nearby watercourses.

Recommended Cost for Alternative Treatment Method. The dust is mixed with hydrated lime, wetted with water and hauled to a chemical landfill. The major equipment components include a 17 m^3 (600 ft^3) dust bin, a 2.3 m^3 (80 ft^3) lime storage tank, a 5 cm (2 in) screw conveyor for feeding the lime and a 5 m (15 ft) long D section conveyor to load the mixture into a dump truck.

Two man-hours per day are assigned to the operation. Lime use for a year is 64 metric tons (70 s. tons). The waste has no recovery value.

The cost for the proposed alternative method of waste disposal as shown in Figure 19 is summarized in Table 30 .

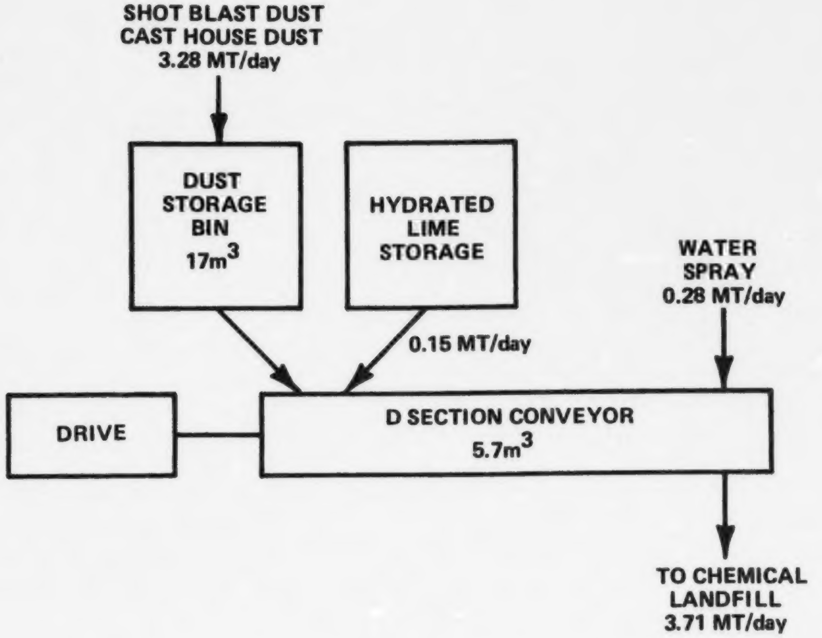
SHOT BLAST DUST
CAST HOUSE DUST
3.28 MT/day
DUST STORAGE BIN
17m3
HYDRATED LIME STORAGE
WATER SPRAY
0.28 MT/day
0.15 MT/day
DRIVE
D SECTION CONVEYOR
5.7m3
TO CHEMICAL LANDFILL
3.71 MT/day

Figure 19. SCHEMATIC FLOW DIAGRAM OF ALTERNATIVE PROCESS FOR PRIMARY ALUMINUM SHOT BLAST AND CAST HOUSE DUST DISPOSAL (WASTE STREAM NUMBER 22)

TABLE 30

Capital and Annual Operating Costs for Alternative Disposal of Primary Aluminum Shot Blast and Cast House Dust (Waste Stream Number 22)

ANNUAL PRODUCTION (METRIC TONS): 153,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 1,100 **WET WEIGHT** -

CAPITAL COST		
FACILITIES		
EQUIPMENT		
Dust Storage Bin	$5,600	
Lime Storage Bin	1,100	
Lime Feeder	2,100	
D Section Conveyor	900	
Piping	300	
Installation	9,700	$19,700
CONTINGENCY		3,900
TOTAL CAPITAL INVESTMENT		$ 23,600
ANNUAL COST		
AMORTIZATION		$ 3,850
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$9,450	
EQUIPMENT REPAIR AND MAINTENANCE	940	
MATERIALS	3,530	
WASTE DISPOSAL	64,120	
TAXES AND INSURANCE	940	$78,980
ENERGY		30
TOTAL ANNUAL COST		$82,860
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS		-
DRY BASIS		$75.33
COST/METRIC TON OF PRODUCT		0.54

SHORT TONS = 0.9 x METRIC TON

G. Pyrometallurgical Antimony Manufacture - Blast Furnace Slag (Waste Stream Number 23)

Waste Description. There are only two locations in the United States producing blast furnace slag from primary antimony production. One location is in Laredo, Texas and the other is in Montana. In 1974, 97% of the antimony metal produced in the United States was from the Laredo, Texas smelter.[1] Blast furnace slag is produced as a waste product from the blast furnace smelting of oxide and sulfide ores of antimony to recover pure antimony metal.

Blast furnace slag is produced at a rate of 2,800 kg/MT of antimony metal. The slag is glassy and hard and produced in large chunks. The typical plant producing 2,700 MT/yr of antimony metal generates 7,560 MT of blast furnace slag. Principal constituents of slag are silicon dioxide, ferrous oxide, calcium oxide, aluminum oxide, and antimony oxide. Other elements known to be contained in slag in low concentrations include lead, copper, zinc, arsenic, cadmium, chromium, nickel, and selenium. These are shown as follows:

Slag Analysis (ppm)[1]

Lead	66
Copper	50
Zinc	500
Antimony	18,000

Solubility Tests Filtrate Analyses (mg/l)[1]

Arsenic	3	Lead	< 0.2
Cadmium	0.09	Antimony	100
Chromium	< 0.01	Zinc	1.7
Copper	5	Selenium	< 0.05
Manganese	0.01	pH	9.2
Nickel	< 0.05		

Potentially hazardous constituents of blast furnace slag which may leach into groundwaters include antimony, copper, zinc, and arsenic.

Present Methods for Waste Disposal. At the present time, blast furnace slag is open dumped on land disposal areas. The permeability of the soils at the land disposal areas is not known. There would be a danger of ground or surface water contamination if potentially hazardous metal constituents leached through permeable soils to groundwater or were carried in surface runoff.

Recommended Alternative Treatment Method. The antimony content of discarded blast furnace slag is from 1 to 2% and processing this slag for further recovery of antimony is not considered economical. Disposal of the lime treated slag in a chemical landfill would be an alternative method for protection of ground and/or surface water from heavy metal leaching. Maintenance of elevated pH's in the land disposal environment will detoxify the heavy metals as insoluble hydroxide precipitates.

The chemical landfill procedure alternates layers of slag with hydrated lime. Thus, a one meter layer of slag underlain by 0.1 meter of hydrated lime would be covered by 0.1 meter of hydrated lime. This layered arrangement is used until the site is filled and then covered by 0.3 m of clay.

The volume occupied by 21.6 MT of blast furnace slag generated in one day is estimated as 14 m^3 (500 ft^3). The area occupied by one day generation of slag piled to a depth of 1.2 m will be 11.1 m^2. Approximately 490 m^2 area will be required to deposit a one year accumulation of alternating layers of slag and lime to a 10 meter depth.

At the present time, producers of primary antimony metal are not using the described alternative method. The benefits to be derived from use of this method are the immobilization of any leachable toxic heavy metals as the metal hydroxides in the lime layers thereby precluding possible movement to ground or surface waters. There will be a 10% volume increase of waste in the landfill due to the use of lime.

Cost for Alternative Method of Waste Disposal. The treatment process is essentially a chemical landfill operation augmented by the addition of hydrated lime between layers of slag. A lime storage shed is provided at the disposal site. Approximately 223 metric tons (245 s. tons) of lime are used each year. The incremental labor, beyond operation of the landfill is estimated to be two hours daily. The waste has no recovery value.

The disposal system flow scheme is shown in Figure 20 and the associated costs are summarized in Table 31.

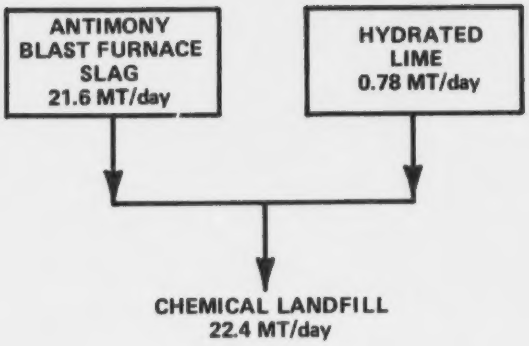
ANTIMONY
BLAST FURNACE
SLAG
21.6 MT/day
HYDRATED
LIME
0.78 MT/day
CHEMICAL LANDFILL
22.4 MT/day

Figure 20. DIAGRAM OF ALTERNATIVE DISPOSAL FOR BLAST FURNACE SLAG FROM PYROMETALLURGICAL ANTIMONY MANUFACTURE. (WASTE STREAM NUMBER 23)

TABLE 31

Capital and Annual Operating Costs for Alternative Disposal of Blast Furnace Slag from Primary Antimony Pyrometallurgical Manufacture (Waste Stream Number 23)

ANNUAL PRODUCTION (METRIC TONS): 2,700

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 7,700 **WET WEIGHT** ____

CAPITAL COST		
FACILITIES		
Lime Storage Shed		$3,600
EQUIPMENT		
CONTINGENCY		700
TOTAL CAPITAL INVESTMENT		$4,300
ANNUAL COST		
AMORTIZATION		700
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$ 9,450	
EQUIPMENT REPAIR AND MAINTENANCE	170	
MATERIALS	12,270	
WASTE DISPOSAL	118,940	
TAXES AND INSURANCE	170	141,000
ENERGY		
TOTAL ANNUAL COST		$141,700
RECOVERY VALUE		-
NET ANNUAL COST		

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS		-
DRY BASIS		$18.40
COST/METRIC TON OF PRODUCT		52.48

SHORT TONS = 0.9 x METRIC TON

H. Electrolytic Antimony Manufacture - Spent Anolyte Sludge (Waste Stream Number 24)

Waste Description. Electrolytic antimony metal is produced by a leaching-electrolysis process. In this process, a complex copper-antimony sulfide ore concentrate is leached with sodium sulfide to dissolve the antimony. The leach solution containing solubilized antimony as sodium thioantimonate (Na_3SbS_4) is electrolyzed in diaphragm cells to yield antimony metal. Although electrolyte is recirculated, the gradual buildup of impurities requires that spent anolyte solution be discharged. Approximately 13 m^3 of spent anolyte solution containing 540 kg of solids is discharged per day. The solids generation rate is 210 kg/MT of antimony metal produced. For the typical plant producing 900 MT/yr of antimony by the electrolytic process, 190 MT dry weight of spent anolyte sludge is generated.

Spent anolyte sludge is composed primarily of metal sulfides. The major metallic constituent is iron. Antimony will be present in the sludge in the order of 2-3% dry weight but is not present in sufficient concentration for economical reprocessing. Other metals present in trace amounts include arsenic, lead, copper, zinc, nickel and cadmium which can pose a hazard to ground or surface water if leached from the sludge. These concentrations are shown following:

Analysis of the Dried Anolyte Solids in ppm:[1]

Arsenic	16	Nickel	5
Lead	5	Antimony	27,000
Copper	50	Chromium	32
Zinc	2	Cadmium	1

Solubility Test Filtrate Analysis mg/l:[1]

Cadmium	0.22	Lead	0.3
Chromium	< 0.01	Antimony	1.6
Copper	0.27	Zinc	0.5
Manganese	0.03	pH	11.0
Nickel	< 0.05		

Present Methods for Waste Disposal. At the present time, spent anolyte solution containing solids is sent to an unlined mine-mill tailings pond. The 13 m^3 daily discharge represents less than 1% of the waste flow from the mine-mill complex. This discharge could contribute to contamination of groundwater if percolation of leached toxic constituents occurs.

Recommended Alternative Treatment Method. At 2% antimony content and 90% recovery efficiency, only 10 kg of antimony metal per day could be extracted from the spent anolyte sludge. Thus resource recovery is not a viable alternative for waste disposal.

Solids contained in the spent anolyte may be isolated from the groundwater environment by a simple process as shown in Figure 21. In this process, the 13 m^3/day of spent anolyte are clarified for solids removal. Solids settled in the clarifier would accupy 1.4 m^3, and clarifier overflow amounting to 12 m^3/day would be discharged to the mine-mill tailings pond. The clarifier sludge would be put into 55-gallon drums and trucked to a chemical landfill. It is estimated that five 55-gallon drums would be required for disposal of the sludge generated in one day.

By using the procedure previously described, it is possible to isolate the settled anolyte solids for environmentally sound disposal in a chemical landfill. The clarifier overflow, however, is not isolated from the environment. This overflow will have high concentrations of nontoxic dissolved solids such as sodium sulfate, sodium thiosulfate and sodium hydroxide. Dissolved heavy metals will be present in the clarifier overflow at very low concentrations. The 12 m^3 clarifier overflow will be less than 1% of total discharge to the tailings pond as previously discussed and the nontoxic dissolved solids will be diluted to relatively low concentrations.

The proposed alternative method of sludge disposal is not commonly practiced by the industry.

Cost for Alternative Method of Waste Disposal. The flow scheme for the disposal of these wastes by the described alternative method is shown in Figure 21 and the cost is summarized in Table 32.

A settling tank, sized for 24 hour retention (1.5 m^3 - 400 gal) is provided. The underflow is containerized and sent to a chemical landfill. About 326 m^3 (425 yd^3) of waste are disposed annually. The waste has no value.

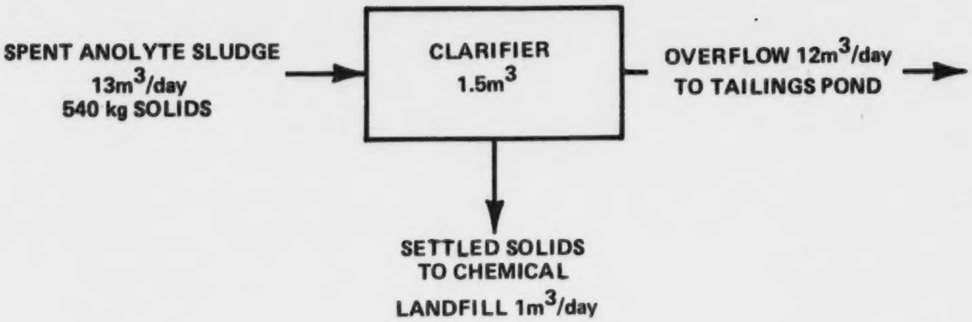
SPENT ANOLYTE SLUDGE
13m³/day
540 kg SOLIDS
CLARIFIER
1.5m³
OVERFLOW 12m³/day
TO TAILINGS POND
SETTLED SOLIDS
TO CHEMICAL
LANDFILL 1m³/day

Figure 21. FLOW DIAGRAM SHOWING CHEMICAL LANDFILL OF SPENT ANOLYTE SLUDGE SOLIDS (WASTE STREAM NUMBER 24)

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TABLE 32

Capital and Annual Operating Costs for Alternative Disposal of Spent Anolyte Sludge from Primary Antimony Electrolytic Manufacture (Waste Stream Number 24)

ANNUAL PRODUCTION (METRIC TONS): 900

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 200 **WET WEIGHT** 600

CAPITAL COST		
FACILITIES		
EQUIPMENT		
Clarifier	$1,500	
Valve and Piping	100	
Installation	1,600	$3,200
CONTINGENCY		600
TOTAL CAPITAL INVESTMENT		$3,800
ANNUAL COST		
AMORTIZATION		$ 620
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	(Included in Waste Disposal Cost)	
EQUIPMENT REPAIR AND MAINTENANCE	$ 150	
MATERIALS		
WASTE DISPOSAL	32,110	
TAXES AND INSURANCE	150	32,410
ENERGY		
TOTAL ANNUAL COST		$33,030
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS		$55.05
DRY BASIS		165.15
COST/METRIC TON OF PRODUCT		36.70

SHORT TONS = 0.9 x METRIC TON

I. Titanium Manufacture - Chlorinator Condenser Sludge
(Waste Stream Number 25)

Waste Description. In the production of titanium sponge metal, rutile (TiO_2) concentrates are treated with chlorine gas to convert the rutile to $TiCl_4$ gas which is then condensed, reduced, and purified to produce titanium sponge. The chlorinator-condenser sludge contains impurities in the rutile plus some carbon, chlorine, and titanium.

Chlorination sludge is generated at a rate of 330 kg/MT of titanium metal product. The typical plant producing 7,600 MT/yr of titanium sponge generates 2,500 MT/yr of sludge. The sludge contains approximately 23% solids and 77% moisture.

Sludge from the chlorination and condensation processes has been found to be about 40% water soluble.[1] The water soluble portion contains chloride and chloride-oxide complexes of chromium, titanium, vanadium and other heavy metals. These are shown as follows:

Sludge Analyses[2] (ppm)

Vanadium	25,780
Chromium	11,630
Zinc	34,770
Titanium	104,400
Chlorine	187,000

Because the high solubility of heavy metals in this sludge and the danger of hydrochloric acid fumes emanating from a disposal environment, titanium chlorinator condenser sludges are considered potentially hazardous if disposed on land.

Present Methods for Waste Disposal. At the present time, the two plants producing titanium sponge metal employ contract disposal services for sludge disposal. One of these firms uses a landfill while the second disposes its sludge in lagoons constructed in highly impermeable glacial till and clay underlain by shale. The type and permeability of soils at the landfill site of a typical plant are not known. Since toxic heavy metal and chloride constituents are easily solubilized from this sludge, contamination of groundwater or surface water is a potential environmental hazard.

Recommended Alternative Treatment Method. On a dry basis, chlorination sludge contains 52% carbon and 38% rutile (TiO_2). The U.S. Bureau of Mines has found in laboratory pilot studies that rutile and carbon can be recovered from the sludge and recycled back to the process for recovery of titanium.[2] The carbon is useful as a reductant in the process.

Figure 22 illustrates the schematic flow for this full scale resource recovery process. The sludge from the chlorinator and condenser totals

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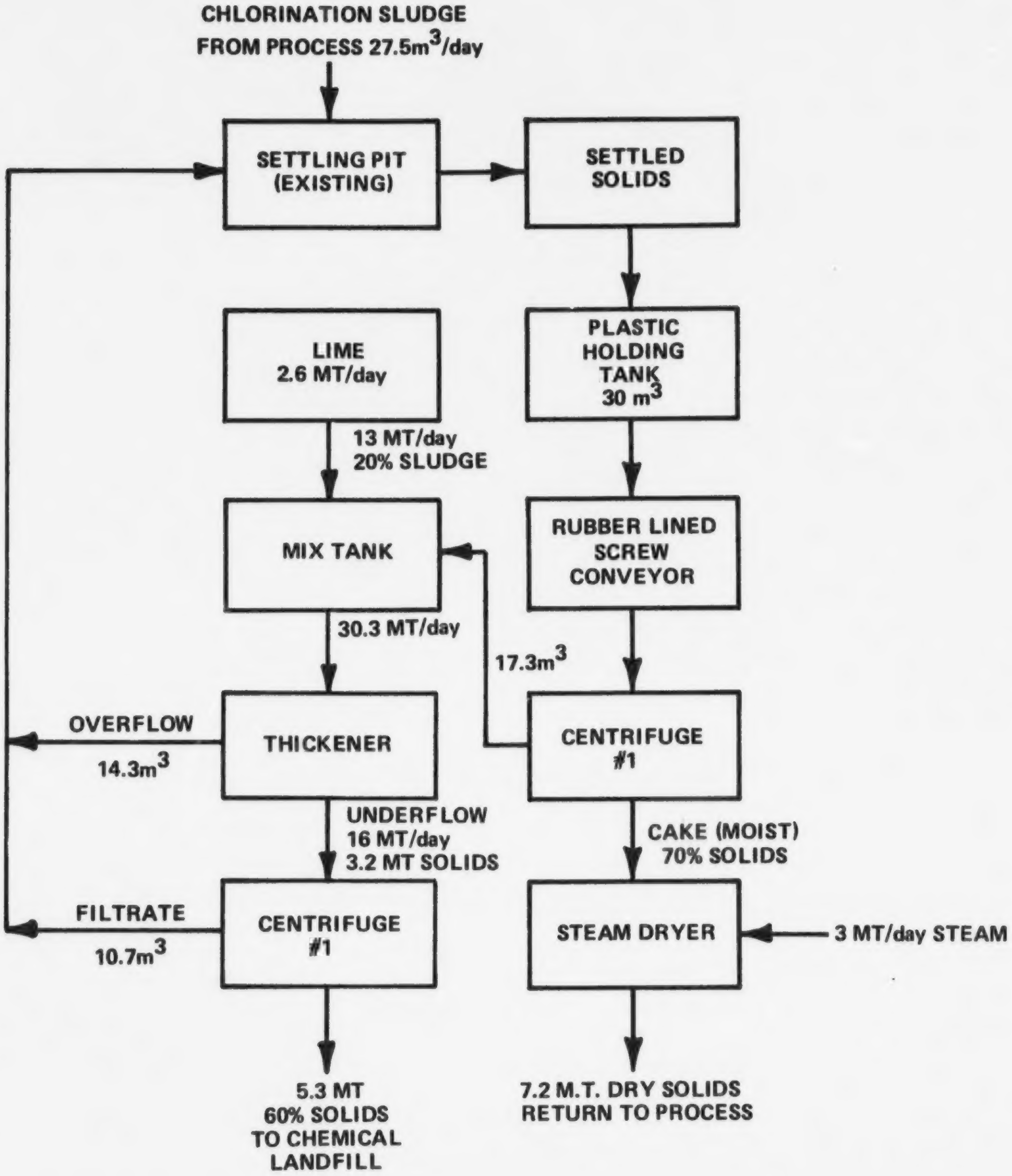
CHLORINATION SLUDGE
FROM PROCESS 27.5m3/day
SETTLING PIT (EXISTING)
SETTLED SOLIDS
LIME 2.6 MT/day
PLASTIC HOLDING TANK 30 m3
13 MT/day
20% SLUDGE
MIX TANK
RUBBER LINED SCREW CONVEYOR
30.3 MT/day
17.3m3
OVERFLOW
14.3m3
THICKENER
CENTRIFUGE #1
UNDERFLOW
16 MT/day
3.2 MT SOLIDS
CAKE (MOIST)
70% SOLIDS
FILTRATE
10.7m3
CENTRIFUGE #1
STEAM DRYER
3 MT/day STEAM
5.3 MT
60% SOLIDS
TO CHEMICAL
LANDFILL
7.2 M.T. DRY SOLIDS
RETURN TO PROCESS

Figure 22. SCHEMATIC FLOW DIAGRAM FOR RECOVERY OF RUTILE AND CARBON FROM CHLORINATOR CONDENSER SLUDGE (WASTE STREAM NUMBER 25)

27.5 m^3/day, is settled in a pit and then transferred to a plastic holding tank. From the holding tank, the sludge is transferred by a screw conveyor to a centrifuge for dewatering. The sludge cake from the centrifuge containing 70% solids is then further dried in a steam dryer. From the steam dryer, 7 MT of dry solids per day can be recycled to the chlorinator for recovery of titanium. The dry solids will contain 2.7 MT of rutile (TiO_2) or 1.7 MT of elemental titanium. Approximately 3.7 MT of carbon is recovered per day.

The waste filtrate from the centrifuge amounting to 17 m^3/day is mixed with lime, thickened, and centrifuged. The precipitated solids are chemically landfilled. The filtrates are recycled to the (existing) settling pit.

The benefits attributable to rutile and carbon recovery from chlorination sludge are resource recovery, waste volume reduction, and elimination of potential ground and surface water contamination which could result when the sludge is deposited in landfills or lagoons.

Cost for Alternative Method of Waste Disposal. A summary of the costs shown in Table 33 was developed based on the flow scheme outlined in Figure 22.

The major system components include a 30 m^3 (7,900 gal) holding tank, a screw conveyor, centrifuge and steam dryer. The screw conveyor is mounted under the holding tank and feeds the sludge to the centrifuge. The centrifuge discharge is directed to a steam dryer and then recycled. The centrifuge filtrate flows to a 19 m^3 (5,000 gal) holding tank from which it is pumped to an existing settling pit.

Operations are conducted 8 hours per day and assigned 4 man-hours of labor. The steam dryer is estimated to use 12.7 x 10^9 joules (12 x 10^6 Btu's) per day.

The recovered product contains 30% rutile. Rutile has a value of about $230 per metric ton ($210/s. ton) which price is used to compute the value of the recovered material.

TABLE 33

Capital and Annual Operating Costs for Alternative Treatment of Chlorinator Condenser Sludge in Primary Titanium Manufacturing (Waste Stream Number 25)

ANNUAL PRODUCTION (METRIC TONS): 7,600

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 2,500 **WET WEIGHT** 6,300

CAPITAL COST		
FACILITIES		
EQUIPMENT		
Holding Tanks	$ 7,000	
Screw Conveyor	2,800	
Centrifuge	46,000	
Steam Dryer	54,000	
Pump	900	
Piping	1,800	
Installation	85,700	$198,200
CONTINGENCY		39,600
TOTAL CAPITAL INVESTMENT		$237,800
ANNUAL COST		
AMORTIZATION		$ 38,760
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$18,900	
EQUIPMENT REPAIR AND MAINTENANCE	9,510	
MATERIALS		
WASTE DISPOSAL		
TAXES AND INSURANCE	9,510	$ 37,920
ENERGY		2,290
TOTAL ANNUAL COST		$ 78,970
RECOVERY VALUE		172,500
NET ANNUAL COST		$ 93,530 *

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS	$ 14.85*	$12.53
DRY BASIS	37.41*	31.59
COST/METRIC TON OF PRODUCT	12.31*	10.39

* = Net gain from alternative treatment

SHORT TONS = 0.9 x METRIC TON

SECTION III

SECONDARY NON-FERROUS REFINING HAZARDOUS WASTES

A. Copper Refining - Blast Furnace Slag
(Waste Stream Number 27)

Waste Description. Copper recovered from high grade scrap (i.e. predominantly copper metal scrap) is refined in reverbatory furnaces. Slag from reverbatory furnaces containing recoverable amounts of copper along with low grade scrap, drosses and skimmings are smelted in blast furnaces. The slag from the blast furnace is too low in copper content for further copper extraction and is, therefore, discarded. Approximately 350 kg of discarded slag is generated for every metric ton of copper metal produced. For a typical plant producing 10,000 MT/yr of secondary copper, 3,500 MT of discarded slag is generated per year. It is estimated that the typical secondary smelter will operate its blast furnace about 100 days per year generating 35 MT of slag per day.

Although this material is dense and hard, solubility tests showed significant concentrations of soluble zinc, cadmium, copper and lead and this waste slag is, therefore, considered potentially hazardous.[1]

Solubility Tests Filtrate Data in mg/l[1]:

Zinc	55	Lead	6
Cadmium	1.0	Antimony	< 0.2
Chromium	0.03	Tin	< 0.2
Copper	170	pH	9.4
Manganese	0.3		

Present Waste Disposal Methods. At the present time, blast furnace slag is open dumped on land. This practice is environmentally unsound if heavy metals (including zinc, copper, lead, and cadmium) leach and percolate through permeable soils to contaminate groundwater. Soil conditions at individual slag disposal sites would determine the degree of potential hazard.

Recommended Alternative Method Treatment. Since the industry already recovers the maximum amount of copper from slags, further attempts at copper recovery is not considered practical nor technically and economically feasible. The concentrations of tin, lead, and zinc are also too low (1% or less) for economical recovery. Other metals such as iron, silicon or aluminum are not valuable enough to warrant recovery.

Detoxification with lime to precipitate soluble heavy metals as low solubility metal hydroxides is a recommended alternative to prevent groundwater contamination which could result from land disposal of blast furnace slag.

A system for lime treatment of blast furnace slag is given in Figure 23. In this system, generated slag is layered with hydrated lime and wetted in a chemical landfill. The hydrated lime requirement ($Ca(OH)_2$) is estimated at 100 kg (215 lbs) per day.

Cost for Alternative Method of Disposal. A schematic diagram of the flow scheme for detoxification of secondary copper refining blast furnace slag is shown in Figure 23. The costs are summarized in Table 34.

The treatment process is a chemical landfill operation augmented by the addition of lime between layers of slag. The lime may be wetted following its application. Approximately 100 kg of hydrated lime are used daily.

A small storage shed is provided at the landfill. The incremental labor beyond operation of the landfill is estimated to be 1 hour daily. The waste has no recovery value.

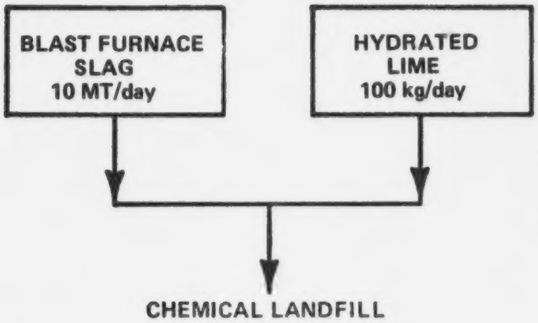
BLAST FURNACE SLAG 10 MT/day
HYDRATED LIME 100 kg/day
CHEMICAL LANDFILL

Figure 23. DIAGRAM OF ALTERNATIVE DISPOSAL FOR BLAST FURNACE SLAG FROM SECONDARY COPPER REFINING (WASTE STREAM NUMBER 27)

TABLE 34

Capital and Annual Operating Costs for Alternative Treatment of Blast Furnace Slag from Secondary Copper Refining (Waste Stream Number 27)

ANNUAL PRODUCTION (METRIC TONS): 10,000

ANNUAL WASTE (METRIC TONS): DRY WEIGHT 3,500 WET WEIGHT --

CAPITAL COST		
FACILITIES		
Lime storage shed		$ 1,100
EQUIPMENT		
CONTINGENCY		200
TOTAL CAPITAL INVESTMENT		$ 1,300
ANNUAL COST		
AMORTIZATION		$ 210
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$ 4,730	
EQUIPMENT REPAIR AND MAINTENANCE	50	
MATERIALS	1,910	
WASTE DISPOSAL	125,560	
TAXES AND INSURANCE	50	$132,300
ENERGY		210
TOTAL ANNUAL COST		$132,510
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	NET	TOTAL
WET BASIS		--
DRY BASIS		$37.86
COST/METRIC TON OF PRODUCT		13.25

SHORT TONS = 0.9 x METRIC TON

B. Lead Refining - SO_2 Scrubwater Sludge
(Waste Stream Number 28)

Waste Description. In the secondary lead smelting process, lead scrap materials such as used lead batteries are smelted in blast or cupola furnaces. Scrap iron is used as the reducing agent to convert lead compounds to metallic lead. During the smelting process, sulfur compounds, such as lead sulfate present in lead battery paste and residual sulfuric acid in scrap batteries are reduced to sulfur dioxide (SO_2) and discharged in air emissions. Scrubbing SO_2 from air emissions with lime solutions produces a predominantly calcium sulfate-calcium sulfite sludge.

The solids content of the settled sludge amounts to 45 kg/MT of lead metal recovered from scrap. A typical plant producing 10,000 MT/year of lead product generates dry sludge solids from SO_2 emission control estimated at 450 metric tons. Daily sludge production totals 3.6 m^3 containing 1.3 MT of solids and 3 MT of water.

The sludge solids resulting from settling of lime scrubwater contain as much as 5% lead and trace concentrations of cadmium, antimony, and other heavy metals in addition to $CaSO_4$ and $CaSO_3$.[1] This sludge is considered potentially hazardous because of the possible solubilization of toxic constituents including lead and cadmium in a land disposal environment.

Analytical data on dried sludge and filtrates from solubility tests are shown following:

Analysis of Dried Sludge (ppm)[1]:

Cadmium	340	Nickel	5
Chromium	30	Lead	53,000
Copper	20	Antimony	1,000
Manganese	120	Zinc	25

Solubility Test Filtrate Analyses (mg/l)[1] :

Zinc	1.3	Lead	2.5
Cadmium	5	Antimony	< 0.2
Chromium	0.05	Tin	1.6
Copper	0.5	pH	8.4
Manganese	0.21		

Present Waste Handling Method. At the present time, SO_2 emissions from secondary lead smelting are scrubbed with lime at only one location. It is expected that scrubbing SO_2 from secondary lead smelting at other locations will become much more prevalent in the future. The lime scrubber solids are presently settled out in an unlined lagoon. Leaching toxic metal constituents including lead and cadmium with subsequent percolation to groundwater could pose a threat to groundwater quality if soils are sufficiently permeable and have low attenuation of metals from leachate. Soil conditions and permeability at the one site are not known, and these would determine the degree of hazard.

Recommended Alternative Treatment Method. Figure 24 illustrates a system for treatment of SO_2 scrubwater sludge which will eliminate the threat of groundwater pollution. In this system, the settled solids from the SO_2 lime scrubber are detoxified with additional lime and sodium sulfide to precipitate soluble toxic metals as insoluble hydroxides and sulfides. The daily lime requirement beyond that which is presently used in the lime scrubber is estimated as 4.5 kilograms (10 lbs) for the typical plant producing 30 MT lead per day. The daily sodium sulfide requirement is estimated as 0.5 kilograms (0.1 lb). A concrete sump should be used to hold sludge prior to treatment.

The lime-sulfide sludge containing 30% solids would then be centrifuged to increase solids to 85%. The centrifuge cake amounting to 1.4 MT/day would be put in 55 gallon drums and hauled to a chemical landfill. Recycle for lead recovery is not practical since lead content of sludge solids will be less than 0.1 MT/day. It is estimated that daily volume of centrifuged material is 0.7 m^3/day and would therefore require four 55 gallon drums.

Filtrate from the centrifuge amounting to 3 m^3/day would be recycled as scrubber water.

Cost for Alternative Method of Disposal. Costs for the flow scheme described in Figure 24 are summarized in Table 35.

The sludge is pumped from a concrete-lined sump into a 3.8 m^3 (1,000 gal) mixing tank where hydrated lime and sodium sulfide are added. The sludge is then centrifuged. The centrifuge discharge is put into a chemical landfill and the filtrate returned to an existing pond.

The equipment is operated 4 hours per day with 2 man-hours of labor. About 1.6 metric tons (1.8 s. tons) of lime and 16 kg (35 lb) of sodium sulfide are used annually. The yearly waste sent to landfill totals 256 m^3 (335 s. tons). The waste has no recovery value.

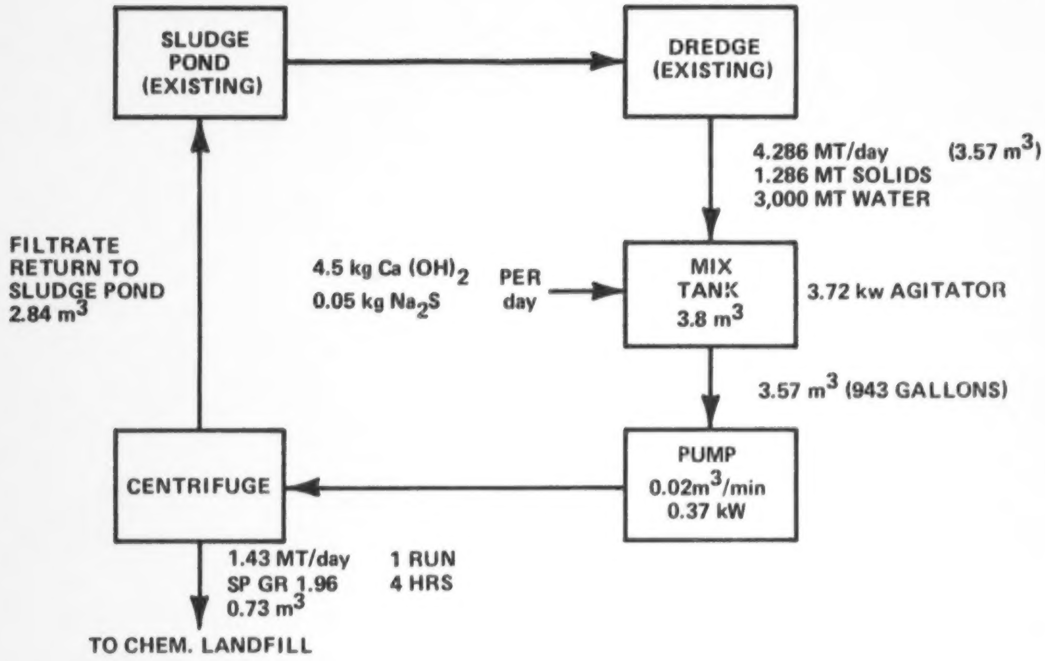
SLUDGE POND (EXISTING)
DREDGE (EXISTING)
4.286 MT/day (3.57 m^3)
1.286 MT SOLIDS
3,000 MT WATER
FILTRATE RETURN TO SLUDGE POND 2.84 m^3
4.5 kg $Ca(OH)_2$
0.05 kg Na_2S
PER day
MIX TANK 3.8 m^3
3.72 kw AGITATOR
3.57 m^3 (943 GALLONS)
PUMP 0.02m^3/min 0.37 kW
CENTRIFUGE
1.43 MT/day
SP GR 1.96
0.73 m^3
1 RUN
4 HRS
TO CHEM. LANDFILL

Figure 24. FLOW DIAGRAM FOR ALTERNATIVE TREATMENT OF SO_2 SCRUBWATER SLUDGE FROM SECONDARY LEAD REFINING (WASTE STREAM NUMBER 28)

TABLE 35

Capital and Annual Operating Costs for Alternative Treatment of SO_2 Scrubwater Sludge - Secondary Lead Refining (Waste Stream Number 28)

ANNUAL PRODUCTION (METRIC TONS): 10,000

ANNUAL WASTE (METRIC TONS): DRY WEIGHT 450 WET WEIGHT 1,500

CAPITAL COST		
FACILITIES		
Concrete Sump		$11,600
EQUIPMENT		
Mix Tank	$ 3,000	
Centrifuge	25,000	
Pumps	1,500	
Piping	1,100	
Installation	23,300	$53,900
CONTINGENCY		13,100
TOTAL CAPITAL INVESTMENT		$78,600
ANNUAL COST		
AMORTIZATION		$12,810
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$9,450	
EQUIPMENT REPAIR AND MAINTENANCE	3,140	
MATERIALS	100	
WASTE DISPOSAL	9,220	
TAXES AND INSURANCE	3,140	$25,050
ENERGY		550
TOTAL ANNUAL COST		$38,410
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	NET	TOTAL
WET BASIS		$25.61
DRY BASIS		85.36
COST/METRIC TON OF PRODUCT		3.84

SHORT TONS = 0.9 x METRIC TON

C. Secondary Aluminum Refining

1. Scrubber Sludge
(Waste Stream Number 29)

Waste Description. High grade aluminum scrap is reclaimed by remelting in pot or rotary furnaces. The smelting of low grade scraps and drosses is performed in reverberatory or rotary furnaces. Common salt and potash mixtures are normally used as fluxing agents to separate impurities from the aluminum metal.

One of the major contaminants in aluminum scrap which must be removed is magnesium metal. In order to remove magnesium (demagging), chlorine gas or aluminum fluoride is injected into the furnace. The chemical reaction which ensues produces acidic gaseous emissions including HCl and HF. These emissions must be scrubbed with a lime slurry to neutralize acidity. Upon settling, the lime slurry produces a sludge. The daily volume of lime sludge generated at a typical secondary aluminum smelter producing 20,000 MT/yr of aluminum (57 MT/day) is 30 m^3. The solids content of the sludge is 4.3 MT/day. Solids generation rate from the lime scrubbing of demagging water is 75 kg/MT of aluminum metal produced.

The scrubber sludge contains a high concentration of fluoride, chloride, and sodium. Trace metals present in significant concentration include copper, lead, and zinc.[1] This waste is considered potentially hazardous because of the possible leaching of fluoride and heavy metals.

Dried Sludge Analyses (ppm)[1]:

Chromium	20
Copper	1,250
Lead	140
Zinc	6,500

Present Waste Handling Methods. At the present time, most secondary aluminum smelters discharge scrubber sludge to unlined lagoons. A few smelters use lined lagoons. The use of unlined lagoons in soils which are permeable could lead to contamination of groundwater by fluoride or heavy metals.

Recommended Alternative Treatment Method. An alternative method for treating scrubber sludge which eliminates lagoons is presented in Figure 25. In this system, dilute lime slurry from emissions scrubbing is first directed to a thickener for initial solids concentration. Overflow from the thickener amounting to 14 m^3/day is recycled to the scrubber.

Further solids concentration to reduce the volume of sludge for final disposal is carried out in a centrifuge. The resultant volume of sludge to be chemically landfilled will be 2.4 m^3 weighing 5 MT. Filtrate from the centrifuge amounting to 10 m^3 per day would be recycled as scrubwater.

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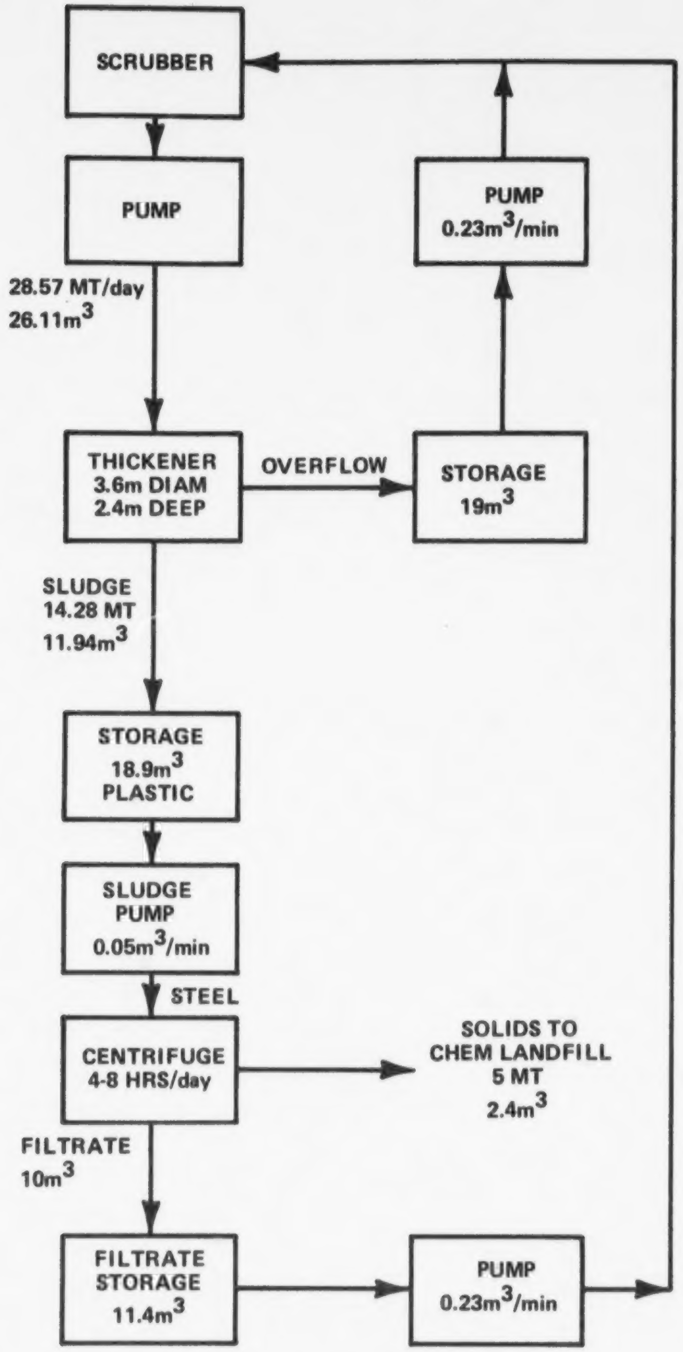
SCRUBBER
PUMP
28.57 MT/day
26.11m3
THICKENER
3.6m DIAM
2.4m DEEP
OVERFLOW
STORAGE
19m3
PUMP
0.23m3/min
SLUDGE
14.28 MT
11.94m3
STORAGE
18.9m3
PLASTIC
SLUDGE
PUMP
0.05m3/min
STEEL
CENTRIFUGE
4-8 HRS/day
SOLIDS TO
CHEM LANDFILL
5 MT
2.4m3
FILTRATE
10m3
FILTRATE
STORAGE
11.4m3
PUMP
0.23m3/min

Figure 25. FLOW DIAGRAM OF ALTERNATIVE SYSTEM FOR SLUDGE TREATMENT AND DISPOSAL FROM SECONDARY ALUMINUM REFINING (WASTE STREAM NUMBER 29)

By using the above system, fluorides and heavy metals are not leached from sludge solids in unlined lagoons. A reduced volume of solids would be safely deposited in a chemical landfill.

Cost for Alternative Method of Disposal. The costs for the flow scheme described in Figure 25 are summarized in Table 36.

The scrubber wastewater flows into a 26 m^3 (7,000 gal) thickener. The overflow is returned to the scrubber. The underflow goes to a 19 m^3 (5,000 gal) storage tank and is then centrifuged. The filtrate discharge from the centrifuge is temporarily stored in a 11.4 m^3 (3,000 gal) storage tank and is pumped to the scrubber. The centrifuge solids are sent to a chemical landfill.

The system is operated 4 hours per day using 2 man-hours. The yearly amount of waste sent to landfill is 840 metric tons (925 s. tons). The waste has no recovery value.

TABLE 36

Capital and Annual Operating Costs for Alternative Treatment of Scrubber Sludge from Secondary Aluminum Refining (Waste Stream Number 29)

ANNUAL PRODUCTION (METRIC TONS): 20,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 1,500 **WET WEIGHT** 5,000

CAPITAL COST		
FACILITIES		
EQUIPMENT		
Storage Tanks	$ 6,000	
Filtrate Storage Tank	2,100	
Centrifuge	30,000	
Thickener	18,000	
Pumps	2,600	
Piping	1,200	
Installation	51,200	$111,100
CONTINGENCY		22,200
TOTAL CAPITAL INVESTMENT		$133,300
ANNUAL COST		
AMORTIZATION		$ 21,730
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$18,900	
EQUIPMENT REPAIR AND MAINTENANCE	5,330	
MATERIALS		
WASTE DISPOSAL	30,240	
TAXES AND INSURANCE	5,330	$ 59,800
ENERGY		1,400
TOTAL ANNUAL COST		$ 82,930
RECOVERY VALUE		
NET ANNUAL COST		

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS		$16.59
DRY BASIS		55.29
COST/METRIC TON OF PRODUCT		4.15

SHORT TONS = 0.9 x METRIC TON

C. Secondary Aluminum Refining

2. High Salt Slag
(Waste Stream Number 30)

Waste Description. The secondary aluminum refining industry processes a wide range of aluminum-bearing wastes for metal recovery. About 10 to 15% of the total secondary aluminum metal recovered is derived from aluminum dross. The recovery of aluminum metal from highly oxidized dross generates large quantities of salt slag which contains fluxing salts (50 to 65%), aluminum metal (5 to 15%), and aluminum oxide (25 to 35%) as major constituents. Minor constituents of interest include chromium (60 ppm), copper (310 ppm), manganese (100 ppm), nickel (10 ppm), lead (300 ppm), and zinc (240 ppm).[1]

For each metric ton of aluminum metal recovered from dross, about 1,400 kg of salt slag is generated. Thus, about 14,000 MT of high salt slag would be produced by a typical secondary aluminum smelter that recovers 10,000 MT of aluminum per year from dross.

Present Disposal Methods. At the present time, nearly all the high salt slag residue from dross processing is disposed of in open dumps. Potassium and sodium chlorides present at high concentrations in high salt slag are relatively nontoxic when compared to heavy metals. However, the high concentration of these constituents and their high solubility presents a potential hazard to groundwater quality. Therefore, open dumping of high salt slag in areas having permeable soils is environmentally unacceptable.

Recommended Alternative Treatment Method. A proposed method for processing high salt slag to allow resource recovery is summarized in Figure 26. This system is based on a process investigated by the Bureau of Mines.[3] The slag is first crushed and then leached with water and a dilute brine. The larger insoluble fractions containing metal are removed by a 16 mesh screen and dried. The 16 mesh fractions and the soluble material are then vacuum filtered. The oxide-containing solids removed in filtering are dried. The filtrate, containing the dissolved salts, is evaporated and the residue is centrifuged. The residual salts are then dried and mixed with cryolite or potassium aluminum fluoride to produce a saleable flux.

The metal-bearing fraction removed by the 16 mesh screen contains about 70% metal and is generated at the rate of 70 kg/MT of slag processed. The oxide fraction removed in vacuum filtering contains 10-12% metallics and is produced at the rate of 330 kg/MT of slag processed. The salt fraction amounts to about 600 kg/MT of slag processed.

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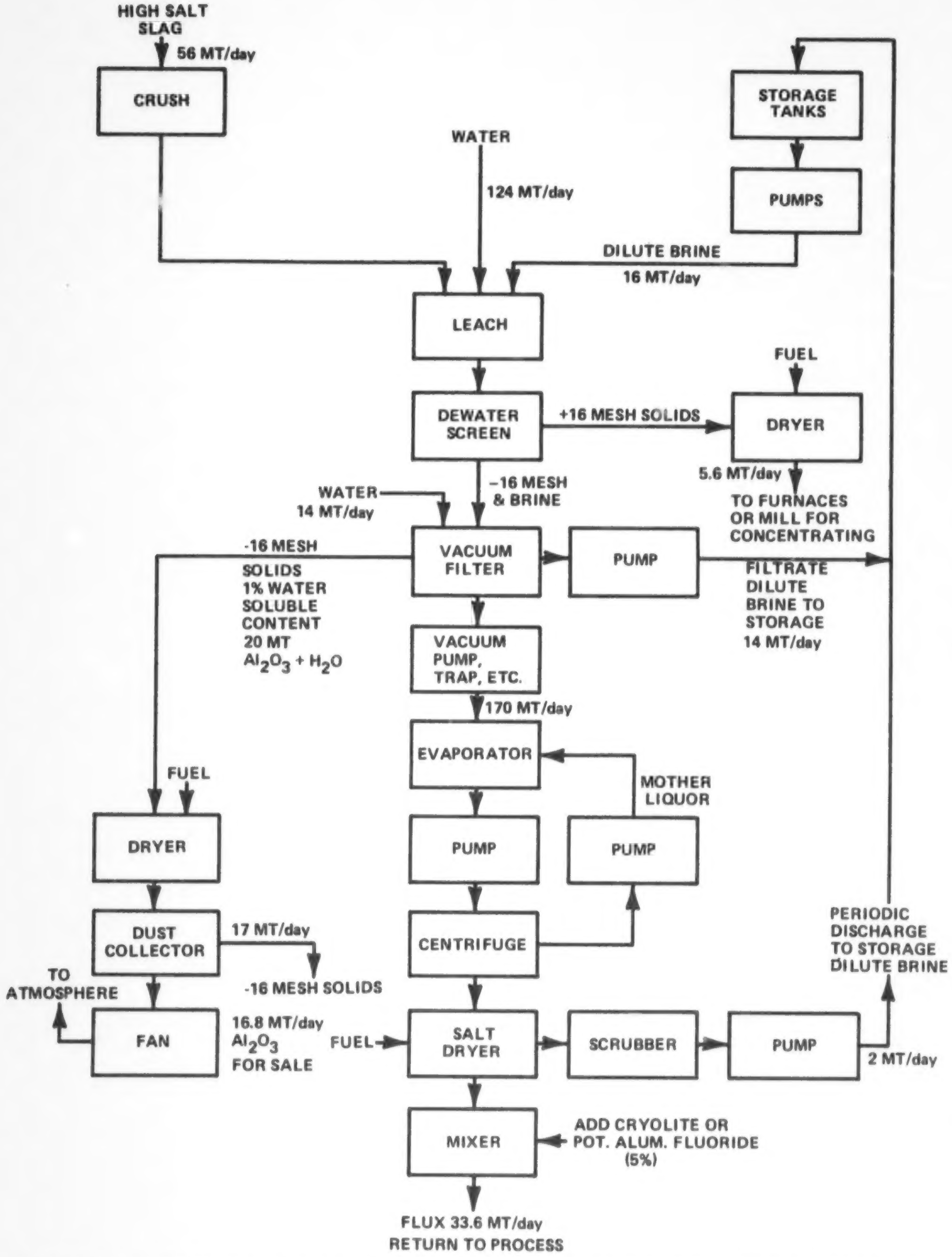
HIGH SALT SLAG
56 MT/day
CRUSH
WATER
124 MT/day
STORAGE TANKS
PUMPS
DILUTE BRINE
16 MT/day
LEACH
FUEL
DEWATER SCREEN
+16 MESH SOLIDS
DRYER
5.6 MT/day
TO FURNACES OR MILL FOR CONCENTRATING
WATER
14 MT/day
–16 MESH & BRINE
-16 MESH
VACUUM FILTER
PUMP
FILTRATE DILUTE BRINE TO STORAGE
14 MT/day
SOLIDS
1% WATER SOLUBLE CONTENT
20 MT
$Al_2O_3 + H_2O$
VACUUM PUMP, TRAP, ETC.
170 MT/day
EVAPORATOR
MOTHER LIQUOR
FUEL
DRYER
PUMP
PUMP
DUST COLLECTOR
17 MT/day
-16 MESH SOLIDS
CENTRIFUGE
PERIODIC DISCHARGE TO STORAGE DILUTE BRINE
TO ATMOSPHERE
FAN
16.8 MT/day
Al_2O_3
FOR SALE
FUEL
SALT DRYER
SCRUBBER
PUMP
2 MT/day
MIXER
ADD CRYOLITE OR POT. ALUM. FLUORIDE (5%)
FLUX 33.6 MT/day
RETURN TO PROCESS

Figure 26. FLOW DIAGRAM FOR SALT RECOVERY FROM HIGH SALT FURNACE SLAG IN SECONDARY ALUMINUM REFINING (WASTE STREAM NUMBER 30)

The proposed system would greatly reduce the amount of waste material requiring land disposal. Most of the by-products can be sold. The only significant amount of waste might be the oxide-containing fraction since local market conditions might not be favorable for this material. Even so, it amounts to only one-third the total weight of the initial slag.

The Bureau of Mines is continuing its research on the process and is presently working on 100 pound batches of high salt slag.

Cost for Alternative Treatment. The alternative process is described in Figure 26 and the costs are summarized in Table 37.

The capital costs and process factors from which the annual costs are derived for this alternative process are based on the Bureau of Mines estimates.[3] The process is operated 8 hours per day with four workers.

Three materials are recovered in the process. Aluminum in the form in which it comes out of the process contains about 70% metal. About 0.7 metric tons (0.8 s. tons) of this concentrate is produced per metric ton of slag processed. A value of $264 per metric ton ($290/s. ton) contained aluminum is assigned to this product.

Approximately 60% of the slag input is recovered as a salt-potash mixture. The mixture is approximately a 1:1 ratio of sodium and potassium chloride. The mixture is valued at $16 per metric ton ($17.60/s. ton), based on 25% of the commercial value of potassium chloride.

The remaining waste, about 33% of the slag input, consists of alumina which can be used in cement plants. Its value depends on the location of the salt recovery plant in relation to cement plants and their need for this material. The alumina is given a value of $12.50 per metric ton ($13.75/s. ton) which is about 25% the value of alumina.

TABLE 37

Capital and Annual Operating Costs for Alternative Treatment of High Salt Slag from Secondary Aluminum Refining (Waste Stream Number 30)

ANNUAL PRODUCTION (METRIC TONS): 10,000

ANNUAL WASTE (METRIC TONS): **DRY WEIGHT** 14,000 **WET WEIGHT** ______

CAPITAL COST		
FACILITIES		$ 150,000
EQUIPMENT		
Installed Equipment		$1,081,000
CONTINGENCY		246,200
TOTAL CAPITAL INVESTMENT		$1,477,200
ANNUAL COST		
AMORTIZATION		240,780
OPERATIONS AND MAINTENANCE (O&M)		
OPERATING PERSONNEL	$151,200	
EQUIPMENT REPAIR AND MAINTENANCE	59,090	
MATERIALS	3,220	
WASTE DISPOSAL		
TAXES AND INSURANCE	59,090	$ 272,600
ENERGY		157,010
TOTAL ANNUAL COST		$ 670,390
RECOVERY VALUE		$ 306,050
NET ANNUAL COST		$ 364,340

COST/METRIC TON OF WASTE	**NET**	**TOTAL**
WET BASIS	-	-
DRY BASIS	$26.02	$47.89
COST/METRIC TON OF PRODUCT	36.43	67.04

SHORT TONS = 0.9 x METRIC TON

SECTION IV

ALTERNATIVE TREATMENT COST ANALYSES

A. Summary of Waste Treatment and Material Recovery Costs

Capital and annual costs for waste treatment and material recovery for the metal manufacturing operations considered in this study are presented in this section. The costs are based on a typical plant and are expressed in 1976 dollars.

The costs, cost factors and costing methodology used to derive the capital and annual costs are documented in Appendix A. Sanitary and chemical landfill costs incurred as part of the alternative waste treatment and material recovery operations are based on the costs developed in Part II.

The alternative treatment and material recovery processes do not necessarily represent optimum systems, with respect to economic efficiency. Rather, the processes are representative of the types of systems and activities which appear applicable for material recovery and waste detoxification and immobilization.

Total annual costs and unit costs per metric ton of waste and product are computed on a total and next basis. The latter cost includes the estimated value of the recovered material. The market values used for the recovered materials are included in the brief descriptions of each waste material.

The alternative waste treatment costs for the industries considered are summarized in Table 38. Implementation of the alternative processes results in net gains for five of the waste streams; i.e., the value assigned to the recovered material exceeds the cost of installing and operating the alternative waste treatment system. These waste streams are:

1. Primary lead smelting sludge, waste stream 17.
2. Primary electrolytic zinc sludge, waste stream 18.
3. Primary pyrometallurgical zinc sludge, waste stream 19.
4. Primary aluminum scrubber sludges, spent pot liners and skimmings, waste streams 20 and 21.
5. Titanium chlorinator condenser sludge, waste stream 25.

Table 38 Summary of Alternative Waste Treatment Costs

Waste Stream	Number	$/Metric Ton of Waste				$/Metric Ton of Product	
		Wet		Dry			
		Total	Net	Total	Net	Total	Net
Iron and Steel Coke Production - Ammonia Still Lime Sludge	1	$ 78.89	$ NRV	$ 259.21	$ NRV	$ 0.07	$ NRV
Iron and Steel Coke Production - Decanter Tank Tar from Coke Production	2	64.58	NRV	324.09	NRV	0.71	NRV
Iron and Steel Prod. - Basic Oxygen Furnace - Wet Emission Control Unit Sludge	3	12.66	7.36	29.90	17.40	0.48	0.28
Iron and Steel Prod.- Open Hearth Furnace - Emission Control Dust	4	12.66	7.36	29.90	17.40	0.48	0.28
Iron and Steel Prod.- Electric Furnace - Wet Emission Control Sludge	5	12.66	7.36	29.90	17.40	0.48	0.28
Iron and Steel Prod.- Rolling Mill Sludge	6	6.46	1.45	16.25	3.65	0.03	0.006
Iron and Steel Prod.- Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	7A	6.85	NRV	27.40	NRV	0.004	NRV

See page 166 for legend.

Table 38 Summary of Alternative Waste Treatment Costs (Cont.)

		$/Metric Ton of Waste				$/Metric Ton of Product	
		Wet		Dry			
Waste Stream	Number	Total	Net	Total	Net	Total	Net
Iron and Steel Prod.-Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (HCl)	7B	$ 6.77	$ NRV	$ 67.67	$ NRV	$ 0.003	$ NRV
Iron and Steel Prod.-Cold Rolling Mill - Waste Pickle Liquor - Sulfuric Acid (H_2SO_4)	8A	55.54	43.31	1,365.82	1,065.24	6.24	4.87
Iron and Steel Prod.-Cold Rolling Mill - Waste Pickle Liquor - Hydrochloric Acid (HCl)	8B	38.38	24.80	449.78	290.63	2.06	1.33
Iron and Steel Prod.-Galvanizing Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	9A	0.99	NRV	3.19	NRV	0.04	NRV
Iron and Steel Prod.-Galvanizing Mill - Acid Rinsewater Neutralization Sludge (HCl)	9B	3.74	NRV	12.47	NRV	0.03	NRV
Ferroalloys - Ferrosilicon Manufacture - Miscellaneous Dusts	11	N.A.	N.A.	15.88	NRV	5.36	NRV

See page 166 for legend.

Table 38 Summary of Alternative Waste Treatment Costs (Cont.)

Waste Stream	Number	$/Metric Ton of Waste				$/Metric Ton of Product	
		Wet		Dry			
		Total	Net	Total	Net	Total	Net
Ferroalloys - Ferrosilicon Manufacture - Slag	12A	$ N.A.	$ N.A.	$ 3.91	$ 2.91	$ 6.85	$ 5.10
Ferroalloys - Ferrosilicon Manufacture - Dust	12B	N.A.	N.A.	18.82	NRV	2.85	NRV
Ferroalloys - Ferrosilicon Manufacture - Sludge	12C	13.88	NRV	34.56	NRV	5.23	NRV
Ferroalloys - Silicomanganese Manufacture - Slag and Scrubber Sludge	13	20.36	18.79	50.80	46.88	15.07	13.91
Ferroalloys - Ferromanganese Manufacture - Slag and Sludge	14	20.36	18.79	50.80	46.88	15.07	13.91
Copper Smelting - Acid Plant Blowdown Sludge	15	379.27	NRV	884.97	NRV	2.65	NRV
Electrolytic Copper Refining - Mixed Sludge	16	360.40	NRV	991.13	NRV	2.48	NRV
Lead Smelting - Sludge	17	6.80	1.01*	22.61	3.36*	1.34	0.20*

See page 166 for legend.

Table 38 Summary of Alternative Waste Treatment Costs (Cont.)

Waste Stream	Number	$/Metric Ton of Waste				$/Metric Ton of Product	
		Wet		Dry			
		Total	Net	Total	Net	Total	Net
Electrolytic Zinc Manufacture	18	$ 16.81	$ 3.50*	$ 56.25	$ 11.20*	$ 1.46	$ 0.29*
Pyrometallurgical Zinc Manufacture - Sludges - Primary Gas Cleaning and Acid Plant Blowdown	19A	3.56	15.44*	11.78	51.08*	1.43	6.21*
Pyrometallurgical Zinc Manufacture - Sludges - Retort Gas Scrubber Bleed	19B	15.30	NRV	30.59	NRV	0.31	NRV
Aluminum Manufacture-Scrubber Sludges	20	35.09	18.35*	27.63	40.59*	13.65	7.14*
Aluminum Manufacture - Spent Potliners and Skimmings	21	35.09	18.35*	27.63	40.59*	13.65	7.14*
Aluminum Manufacture - Shot Blast and Cast House Dusts	22	N.A.	N.A.	75.33	NRV	0.54	NRV

See page 166 for legend.

Table 38 Summary of Alternative Waste Treatment Costs (Cont.)

Waste Stream	Number	$/Metric Ton of Waste				$/Metric Ton of Product	
		Wet		Dry			
		Total	Net	Total	Net	Total	Net
Pyrometallurgical Antimony Manufacture-Blast Furnace Slag	23	$ N.A.	$ N.A.	$ 18.40	$ NRV	$ 52.48	$ NRV
Electrolytic Antimony Manufacture - Spent Anolyte Sludge	24	55.05	NRV	165.15	NRV	36.70	NRV
Titanium Manufacture-Chlorinator Condenser Sludge	25	12.53	14.85*	31.59	37.41*	10.39	12.31*
Copper Refining - Blast Furnace Slag	27	N.A.	N.A.	37.86	NRV	13.25	NRV
Lead Refining - SO_2 Scrubwater Sludge	28	25.61	NRV	85.36	NRV	3.84	NRV
Aluminum Refining - Scrubber Sludge	29	16.59	NRV	55.29	NRV	4.15	NRV
Aluminum Refining - High Salt Slag	30	N.A.	N.A.	47.89	26.02	67.04	36.43

N.A. = Not applicable
* = Net gain, i.e., value of recovered material exceeds cost of alternative treatment
NRV = No recovery value

Nineteen waste streams have alternative treatment costs (net costs where applicable) that were less than $5 per metric ton ($4.50/s. ton) of product. These are:

1. Sulfuric acid waste pickle liquor, waste stream 8A-$4.87
2. Secondary aluminum scrubwater sludge, waste stream 29 - $4.15
3. Secondary lead scrubwater sludge, waste stream 28 - $3.84
4. Ferrochrome dust, waste stream 12 - $2.85
5. Copper smelting, acid plant blowdown sludge, waste stream 15 - $2.85
6. Electrolytic copper mixed sludge, waste stream 16 - $2.48
7. Hydrochloric acid waste pickle liquor, waste stream 8B - $1.33
8. Ammonia still sludge, waste stream 1 - $0.07
9. Primary aluminum shot blast and cast house dusts, waste stream 22 - $0.54
10. Primary zinc pyrometallurgical dust, waste stream 19 - $0.31
11. Primary zinc electrolytic sludge, waste stream 18 - $0.29
12. Steel mill air emission, waste streams 3, 4, and 5 - $0.28
13. Primary lead smelting sludge, waste stream 17 - $0.20
14. Decanter tank tar, waste stream 2 - $0.71
15. Galvanizing mill acid rinsewater neutralizing sludge, waste stream 9A - 0.04
16. Galvanizing mill acid rinsewater neutralizing sludge, waste stream 9B - $0.03
17. Iron and Steel rolling mill sludge, waste stream 6 - $0.006
18. Cold rolling mill acid rinsewater neutralization sludge, waste stream 7A - $0.004
19. Cold rolling mill acid rinsewater neutralization sludge, waste stream 7B - $0.003

Eight waste streams show alternative treatment costs (net costs where applicable) of more than \$5 per metric ton (\$4.50/s. ton) of product. These are:

1. Primary pyrometallurgical antimony slag, waste stream 23 - \$52.48
2. Primary electrolytic antimony sludge, waste stream 24 - \$36.70
3. Secondary aluminum refining high salt slag, waste stream 30 - \$36.43
4. Silico and ferromanganese slag and sludge, waste streams 13 and 14 - \$13.91
5. Secondary copper refining slag, waste stream 27 - \$13.25
6. Ferrosilicon dust, waste stream 11 - \$5.36
7. Ferrochrome sludge, waste stream 12 - \$5.23
8. Ferrochrome slag, waste stream 12 - \$5.10

The determination of the significance of the above costs requires consideration of the value of the product, the industry pricing structure and the overall economic condition of the industries. Such analysis is beyond the scope of this study.

B. Break-Even Analysis

The total annual costs resulting from the alternative treatment processes are compared to the values assigned to the recovered materials in Table 39.

The actual value of the recovered products is largely a function of demand. For the most part, the demand for the recovered product must be geographically near its point of origin. In recognition of these factors, a relatively low value, i.e. a fraction of the reported market value, was assigned to the recovered material. In fact, higher prices than those assumed may be obtainable in the market place. The product values assigned to each of the affected industries and the likelihood of achieving a higher return are breifly discussed below.

Table 39 Break-Even Analysis Between Alternative Treatment Cost and Recoverable Resource Value

Waste Stream	Number	Total Annual Cost	Annual Value of Recovered Material	Percent of Market Price Assigned	Net Annual Cost	Required Percent Increase in Recovered Material Value
Iron and Steel Coke Prod. - Ammonia Still Lime Sludge	1	$ 181,450	$ NRV	N.A.	$ N.A.	N.A.
Iron and Steel Coke Prod. - Decanter Tank Tar from Coke Production	2	1,882,410	NRV	N.A.	N.A.	N.A.
Iron and Steel Production - Basoc Oxygen Furnace - Wet Emission Control Unit Sludge	3	1,195,950	500,000	100[a]	695,950	139
Iron and Steel Production - Open Hearth Furnace - Emission Control Dust	4	1,195,950	500,000	100[a]	695,950	139
Iron and Steel Production - Electric Furnace - Wet Emission Control Sludge	5	1,195,950	500,000	100[a]	695,950	139
Iron and Steel Production - Rolling Mill Sludge	6	50,370	39,060	100[a]	11,310	29

See page 174 for legend.

Table 39 Break-Even Analysis Between Alternative Treatment Cost and Recoverable Resource Value (Cont.)

Waste Stream	Number	Total Annual Cost	Annual Value of Recovered Material	Percent of Market Price Assigned	Net Annual Cost	Required Percent Increase in Recovered Material Value
Iron and Steel Production - Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	7A	$ 2,740	NRV	$ N.A.	$ N.A.	N.A.
Iron and Steel Production - Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (HCl)	7B	2,740	NRV	N.A.	N.A.	N.A.
Iron and Steel Production - Cold Rolling Mill - Waste Pickle Liquor - Sulfuric Acid (H_2SO_4)	8A	4,370,620	961,840	100[b]	3,408,780	354
Iron and Steel Production - Cold Rolling Mill - Waste Pickle Liquor - Hydrochloric Acid (HCl)	8B	1,439,280	509,280	70[c],100[a]	930,000	183
Iron and Steel Production - Galvanizing Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	9A	4,470	NRV	N.A.	N.A.	N.A.

See page 174 for legend.

Table 39 Break-Even Analysis Between Alternative Treatment Cost and Recoverable Resource Value (Cont.)

Waste Stream	Number	Total Annual Cost	Annual Value of Recovered Material	Percent of Market Price Assigned	Net Annual Cost	Required Percent Increase in Recovered Material Value
Iron and Steel Production - Galvanizing Mill - Acid Rinsewater Neutralization Sludge (HCl)	9B	$ 3,740	$ NRV	N.A.	$ N.A.	N.A.
Ferroalloys - Ferrosilicon Manufacture - Miscellaneous Dusts	11	214,400	NRV	N.A.	N.A.	N.A.
Ferroalloys - Ferrosilicon Manufacture - Slag	12A	239,690	61,300	100[d]	178,390	291
Ferroalloys - Ferrosilicon Manufacture - Dust	12B	99,750	NRV	N.A.	N.A.	N.A.
Ferroalloys - Ferrosilicon Manufacture - Sludge	12C	183,150	NRV	N.A.	N.A.	N.A.
Ferroalloys - Silicomanganese Manufacture - Slag and Scrubber Sludge	13	452,090	34,880	25[e]	417,210	1,196

See page 174 for legend.

Table 39 Break-Even Analysis Between Alternative Treatment Cost and Recoverable Resource Value (Cont.)

Waste Stream	Number	Total Annual Cost	Annual Value of Recovered Material	Percent of Market Price Assigned	Net Annual Cost	Required Percent Increase in Recovered Material Value
Ferroalloys - Ferromanganese Manufacture - Slag and Sludge	14	$ 452,090	$ 34,880	25	$ 417,210	1,196
Copper Smelting - Acid Plant Blowdown Sludge	15	265,490	NRV	N.A.	N.A.	N.A.
Electrolytic Copper Refining - Mixed Sludge	16	396,450	NRV	N.A.	N.A.	N.A.
Lead Smelting - Sludge	17	146,970	168,780	25[f]	21,810*	N.A.
Electrolytic Zinc Manufacture	18	146,240	117,100	25[g]	29,140*	N.A.
Pyrometallurgical Zinc Manufacture - Sludges - Primary Gas Cleaning and Acid Plant Blowdown	19A	153,180	817,220	100[g]	(664,040)	N.A.
Pyrometallurgical Zinc Manufacture - Sludges - Retort Gas Scrubber Bleed	19B	33,650	NRV	N.A.	N.A.	N.A.

See page 174 for legend.

Table 39 Break-Even Analysis Between Alternative Treatment Cost and Recoverable Resource Value (Cont.)

Waste Stream	Number	Total Annual Cost	Annual Value of Recovered Material	Percent of Market Price Assigned	Net Annual Cost	Required Percent Increase in Recovered Material Value
Aluminum Manufacture - Scrubber Sludges	20	$2,099,140	$3,180,000	100[h]	$1,091,860	N.A.
Aluminum Manufacture - Spent Potliners and Skimmings	21	2,099,140	3,180,000	100[h]	1,091,860	N.A.
Aluminum Manufacture - Shot Blast and Cast House Dusts	22	82,860	NRV	N.A.	N.A.	N.A.
Pyrometallurgical Antimony Manufacture - Blast Furnace Slag	23	141,700	NRV	N.A.	N.A.	N.A.
Electrolytic Antimony Manufacture - Spent Anolyte Sludge	24	33,030	NRV	N.A.	N.A.	N.A.
Titanium Manufacture - Chlorinator Condenser Sludge	25	78,970	172,500	100[i]	93,530*	N.A.
Copper Refining - Blast Furnace Slag	27	132,510	NRV	N.A.	N.A.	N.A.

See page 174 for legend.

Table 39 Break-Even Analysis Between Alternative Treatment Cost and Recoverable Resource Value (Cont.)

Waste Stream	Number	Total Annual Cost	Annual Value of Recovered Material	Percent of Market Price Assigned	Net Annual Cost	Required Percent Increase in Recovered Material Value
Lead Refining - SO_2 Scrubwater Sludge	28	$ 38,410	$ NRV	N.A.	$ N.A.	N.A.
Aluminum Refining - Scrubber Sludge	29	82,930	NRV	N.A.	N.A.	N.A.
Aluminum Refining - High Salt Slag	30	670,390	306,050	25[j]	364,340	119

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* = Net gain, i.e., value of recovered material exceeds cost of alternative waste treatment
N.A. = Not applicable
NRV = No recovery value

[a] - for iron pellets
[b] - for ferric chloride
[c] - for hydrochloric acid
[d] - for roadfill
[e] - for zinc oxide
[f] - for lead
[g] - for zinc
[h] - for cryolite
[i] - for rutile
[j] - for potassium chloride

Waste Streams No. 3, 4, 5, and 6 - Emission Control Sludges and Dusts in Steel Manufacture. The initial value assigned to the contained iron was based on the price of iron pellets, \$20/per metric ton (\$18/s. ton). This represents about 20% of the value of steel scrap. If, in fact, the recovered material is found to be similar to scrap, a valuation sufficient to achieve the break-even point appears reasonable. The required price would be \$48/metric ton (\$44/s. ton) which represents 80% of the price of low grade scrap.

Waste Stream No. 8A - Sulfuric Acid Waste Pickle Liquor. The product recovered is ferric chloride. Its assigned value is 50% of the product price. Full value pricing would still leave a large gap between alternative process costs and potential revenues generated.

Waste Stream No. 8B - Hydrochloric Acid Waste Pickle Liquor. The recovered materials are hydrochloric acid and iron pellets. The value of the former is computed at 70% of market value; the latter at \$20/metric ton (\$18/s. ton) contained iron is the fall market value. Most of the assigned recovery value obtains from the hydrochloric acid. Break-even operation is not achievable.

Waste Stream No. 12 - Slag from Ferrochrome Manufacture. The recovered material can be used for road construction. Break-even operation requires an increase in the assumed material price of \$1/metric ton (\$0.90/s. ton) to \$2.90/metric ton (\$2.65/s. ton). A reasonable level of demand would justify the higher value.

Waste Streams No. 13, 14 - Sludge from Silico and Ferromanganese. The major metal recovered is zinc. Its assigned value is \$204/metric ton (\$185/s. ton) which represents about 25% of market value. Assigning full value to the recovered zinc and other metals would not result in a break-even operation.

Waste Stream No. 30 - High Salt Slag from Secondary Aluminum Refining. The recovered materials consist of aluminum, potassium chloride and alumina. These materials were priced at 25% of their market values. Break-even operations require that they be priced at about 55% market value. This appears achievable.

In summary, five alternative treatment processes yield recovered materials whose value exceeds the alternative treatment costs of operation; 18 processes do not provide materials with discernible market values. Of the remaining seven alternative processes, four can be expected to reach a break-even point and three cannot.

Wastes with definite recovered material value exceeding alternative treatment costs:

1. Primary lead smelting sludge, waste stream 17
2. Primary electrolytic zinc sludge, waste stream 18
3. Primary pyrometallurgical zinc sludge, waste stream 19A
4. Primary aluminum scrubber sludge, potliners and skimmings, waste streams 20 and 21
5. Primary titanium chlorinator condenser, waste stream 25

Wastes with potential recovered material value exceeding alternative treatment costs:

1. Steel mill emission control sludge and dusts, waste streams 3, 4, and 5
2. Rolling mill sludge, waste stream 6
3. Slag from ferrochrome manufacture, waste stream 12
4. Secondary aluminum high salt slag, waste stream 30

Wastes with recovered materials whose value does not exceed alternative treatment costs:

1. Silico and ferromanganese slag and sludge, waste streams 13 and 14
2. Spent sulfuric acid pickle liquor, waste stream 8A
3. Spent hydrochloric acid pickle liquor, waste stream 8B

Wastes whose alternative treatments do not provide recovered materials:

1. Ammonia still sludge, waste stream 1
2. Decanter tank tar, waste stream 2

3. Sulfuric acid rinsewater neutralization sludge, waste stream 7A
4. Hydrochloric acid rinsewater neutralization sludge, waste stream 7B
5. Sulfuric acid spent pickle liquor, waste stream 9
6. Hydrochloric acid spent pickle liquor, waste stream 9
7. Ferrosilicon - misc. dusts, waste stream 11
8. Dust from ferrochrome manufacturing, waste stream 12
9. Sludge from ferrochorme manufacturing, waste stream 12
10. Copper smelting acid plant blowdown, waste stream 15
11. Electrolytic copper refining - mixed sludge, waste stream 16
12. Pyrometallurgical zinc sludge (primary), waste stream 19B
13. Primary aluminum shot blast and cast house dust, waste stream 22
14. Primary antimony blast furnace slag, waste stream 23
15. Primary antimony spent anolyte sludge, waste stream 24
16. Secondary copper blast furnace slag, waste stream 27
17. Secondary lead SO_2 scrubwater sludge, waste stream 28
18. Secondary aluminum scrubber sludge, waste stream 29

The total annual costs and the break-even analyses of the alternative treatment processes by comparison to the value of recoverable materials are summarized in Table 39. The percent of market value assigned to each recoverable material is also shown in Table 39.

C. Summary of Alternative Treatment Systems and Benefits

The major processes used by the alternative treatment systems, the process category, stage of development and the benefits therefrom are summarized in Table 40.

Table 40 Summary Table of Alternate Treatment Systems, Benefits, Stage of Development, and Costs

Waste Stream	Number	Alternative Treatment Process	Alternative Treatment Process Category	Development Stage	Benefits Derived	$/Metric Ton of Waste Wet Total	$/Metric Ton of Waste Wet Net	$/Metric Ton of Waste Dry Total	$/Metric Ton of Waste Dry Net	$/Metric Ton of Product Total	$/Metric Ton of Product Net
Iron and Steel Coke Production - Ammonia Still Lime Sludge	1	Disposal	P	V	Detoxified, inert solids suitable for chemical landfill	$ 78.89	$ NRV	$ 259.21	$ NRV	$ 0.07	$ NRV
Iron and Steel Coke Production - Decanter Tank Tar from Coke Production	2	Disposal	P	V	Detoxified, inert solids suitable for chemical landfill	64.58	NRV	324.09	NRV	0.71	NRV
Iron and Steel Prod. - Basic Oxygen Furnace - Wet Emission Control Unit Sludge	3	Reduction Roasting	C	V	Ferric oxide recovery for recycle. Lead and zinc oxide recovery for sale.	12.66	7.36	29.90	17.40	0.48	0.28
Iron and Steel Prod.- Open Hearth Furnace - Emission Control Dust	4	Reduction Roasting	C	V	Ferric oxide recovery for recycle. Lead and zinc oxide recovery for sale.	$ 12.66	$ 7.36	$ 29.90	$ 17.40	$ 0.48	$ 0.28
Iron and Steel Prod.- Electric Furnace - Wet Emission Control Sludge	5	Reduction Roasting	C	V	Ferric oxide recovery for recycle. Lead and zinc oxide recovery for sale.	12.66	7.36	29.90	17.40	0.48	0.28
Iron and Steel Prod.- Rolling Mill Sludge	6	Sintering	P	V	Iron recovery for recycle	6.46	1.45	16.25	3.65	0.03	0.006
Iron and Steel Prod.- Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	7A	Dissolution	C	V	Ferric oxide recovery	6.85	NRV	27.40	NRV	0.004	NRV
Iron and Steel Prod.- Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (HCl)	7B	Dissolution	C	V	Ferric chloride recovery	6.77	NRV	67.67	NRV	0.003	NRV
Iron and Steel Prod.- Cold Rolling Mill - Waste Pickle Liquor - Sulfuric Acid (H_2SO_4)	8A	Precipitation	C	III	Ferric chloride for sale, Calcium sulfate (gypsum) for chemical landfill	55.54	43.31	1,365.82	1,065.24	6.24	4.87
Iron and Steel Prod.- Cold Rolling Mill - Waste Pickle Liquor - Hydrochloric Acid (HCl)	8B	Volatilization Reduction Roasting	P C	IV IV	Hydrochloric acid recovered for recycle Ferric oxide recovered for reuse	38.38	24.80	449.78	290.63	2.06	1.33
Iron and Steel Prod.- Galvanizing Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	9A	Dissolution	C	V	Ferric oxide recovered	$ 0.99	$ NRV	$ 3.19	$ NRV	$ 0.04	$ NRV
Iron and Steel Prod.- Galvanizing Mill - Acid Rinsewater Neutralization Sludge (HCl)	9B	Dissolution	C	V	Ferric chloride recovery	3.74	NRV	12.47	NRV	0.03	NRV

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Table 40 **Summary Table of Alternate Treatment Systems, Benefits, Stage of Development, and Costs (Cont.)**

		Alternative Treatment				$/Metric Ton of Waste				$/Metric Ton of Product	
						Wet		Dry			
Waste Stream	Number	Process	Process Category	Development Stage	Benefits Derived	Total	Net	Total	Net	Total	Net
Ferroalloys - Ferrosilicon Manufacture - Miscellaneous Dusts	11	Disposal	P	-	Chemical landfill	N.A.	N.A.	15.88	NRV	5.36	NRV
Ferroalloys - Ferrosilicon Manufacture - Slag	12A	Precipitation	C	V	Detoxification	N.A.	N.A.	3.91	2.91	6.85	5.10
Ferroalloys - Ferrosilicon Manufacture - Dust	12B	Precipitation	C	V	Detoxification	N.A.	N.A.	18.82	NRV	2.85	NRV
Ferroalloys - Ferrosilicon Manufacture - Sludge	12C	Precipitation	C	V	Detoxification	13.88	NRV	34.56	NRV	5.23	NRV
Ferroalloys - Silicomanganese Manufacture - Slag and Scrubber Sludge	13	Reduction Roasting	C	IV	Ferro and silicomanganese for recycle	20.36	18.79	50.80	46.88	15.07	13.91
Ferroalloys - Ferromanganese Manufacture - Slag and Sludge	14	Reduction Roasting	C	IV	Lead and zinc oxide for sale	20.36	18.79	50.80	46.88	15.07	13.91
Copper Smelting - Acid Plant Blowdown Sludge	15	Precipitation	C	V	Detoxification	$379.27	$ NRV	$ 884.97	$ NRV	$ 2.65	$ NRV
Electrolytic Copper Refining - Mixed Sludge	16	Precipitation	C	V	Detoxification	360.40	NRV	991.13	NRV	2.48	NRV
Lead Smelting - Sludge	17	Sintering	P	V	Lead recycled for reprocessing	6.80	1.01*	22.61	3.36*	1.34	0.20*
Electrolytic Zinc Manufacture	18	Precipitation	C	V	Zinc recycled for reprocessing	16.81	3.50*	56.25	11.20*	1.46	0.29*
Pyrometallurgical Zinc Manufacture - Sludges - Primary Gas Cleaning and Acid Plant Blowdown	19A	Sintering	P	V	Zinc recycled for reuse	3.56	15.44*	11.78	51.08*	1.43	6.21*
Pyrometallurgical Zinc Manufacture - Sludges - Retort Gas Scrubber Bleed	19B	Centrifuge	P	V	Zinc recycled for reuse	15.30	NRV	30.59	NRV	0.31	NRV
Aluminum Manufacture-Scrubber Sludges	20	Precipitation Evaporation Dewatering Drying Disposal	P,C	V	Cryolite recovery.	35.09	18.35*	27.63	40.59*	13.65	7.14*
Aluminum Manufacture - Spent Potliners and Skimmings	21		P,C	V	Cryolite recovered for reuse	35.09	18.35*	27.63	40.59*	13.65	7.14*
Aluminum Manufacture - Shot Blast and Cast House Dusts	22	Precipitation	C	V	Detoxification	N.A.	N.A.	75.33	NRV	0.54	NRV

Table 40 **Summary Table of Alternate Treatment Systems, Benefits, Stage of Development, and Costs (Cont.)**

		Alternative Treatment				$/Metric Ton of Waste				$/Metric Ton of Product	
						Wet		Dry			
Waste Stream	Number	Process	Process Category	Development Stage	Benefits Derived	Total	Net	Total	Net	Total	Net
Pyrometallurgical Antimony Manufacture-Blast Furnace Slag	23	Precipitation	C	V	Detoxification	$ N.A.	$ N.A.	$ 18.40	$ NRV	$ 52.48	$ NRV
Electrolytic Antimony Manufacture - Spent Anolyte Sludge	24	Disposal	P	-	Detoxification	55.05	NRV	165.15	NRV	36.70	NRV
Titanium Manufacture-Chlorinator Condenser Sludge	25	Centrifuge Dewatering Recycling	P	III	Titanium dioxide (rutile) and carbon recovered for reuse	12.53	14.85*	31.59	37.41*	10.39	12.31*
Copper Refining - Blast Furnace Slag	27	Precipitation	C	V	Detoxification	N.A.	N.A.	37.86	NRV	13.25	NRV
Lead Refining - SO_2 Scrubwater Sludge	28	Precipitation	C	V	Detoxification	25.61	NRV	85.36	NRV	3.84	NRV
Aluminum Refining - Scrubber Sludge	29	Centrifuge Dewatering	P	V	Volume reduction and chemical landfill	16.59	NRV	55.29	NRV	4.15	NRV
Aluminum Refining - High Salt Slag	30	Crushing & Screening, Dewatering & Drying	P	IV	Aluminum oxide recovered for reuse	N.A.	N.A.	47.89	26.02	67.04	36.43
		Dissolution Evaporation Dewatering Drying	P,C	IV	Flux salts, sodium and potassium chloride						

Alternative Treatment Unit Process Category:

P. - Physical
C. - Chemical

Alternative Treatment Stage of Development:

I Process is not applicable for this waste
II Process needs research effort, might work in 5-10 years
III Process appears useful for hazardous wastes but needs development work
IV Process is developed but not commonly used for hazardous wastes
V Process common to most industrial waste processors

N.A. - Not applicable

* - Net gain, i.e., value of recovered material exceeds cost of alternative treatment

NRV - No recovery value

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(3) "Processing Slag from an Aluminum Dross Furnace to Recover Fluxing Salts, Aluminum Metal and Aluminum Oxide," H.S. Caldwell et al., U.S. Bureau of Mines Paper Presented in Proceedings of the Fourth Mineral Waste Utilization Symposium. Chicago, Ill., May 7, 8, 1974.

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PART II

COST DEVELOPMENT FOR SANITARY AND CHEMICAL LANDFILL DISPOSAL OF HAZARDOUS WASTES FROM THE METALS SMELTING AND REFINING INDUSTRIES

SECTION I

CHEMICAL LANDFILL COST DEVELOPMENT

Disposal of hazardous wastes in chemical or secure landfills is an appropriate disposal process for certain waste materials or for recovery of process waste residues. The approach and method used to derive costs for secure or chemical landfill disposal of wastes is described below. The cost model incorporates major assumptions, costs and cost factors specified by EPA. A chemical landfill cost curve (Figure 1) was developed from landfill designs for 1,000 and 6,000 m^3 of waste as shown following. This range of waste volumes was used because a preliminary review of waste quantities generated by a number of typical plants fell within these values.

Landfill Design No. 1 (1,000 m^3 of waste)

The initial trench excavated has a volume of 1,250 m^3. Covering for the disposed material is estimated to occupy 25 percent of the disposed waste volume. Thus, 1,000 m^3 of waste can be placed in the trench.

The trench is formed with sloping sides (2:1). The dimensions of the trench are:

Width:	Bottom	11 m	Top 15 m
Length:	Bottom	22 m	Top 26 m
Depth:	4 m		

A leachate collection system is installed in the trench. Polyvinyl chloride 10.2 cm (4") drain pipe is installed at 2 m intervals running the length of the trench. These pipes are connected to a transverse drain pipe at one end of the trench.

The trench is lined with bentonite applied at a rate of 9.8 kg/m^2 (18 lb/yd^2). A 30 mil hypalon liner is installed over the bentonite. The lining is placed at the bottom and sides of the trench.

The trench area lined is 700 m^2 (840 yd^2). Local on-site clay is placed at one end and bottom of the trench to a depth of 0.6 m (2 ft) for protection of the liner during vehicle operation. Local clay is also used for cover of the disposed material. At completion, the surface of the trench is sealed with a bentonite liner. The total area occupied by the trench is 600 m^2 (0.15 acres).

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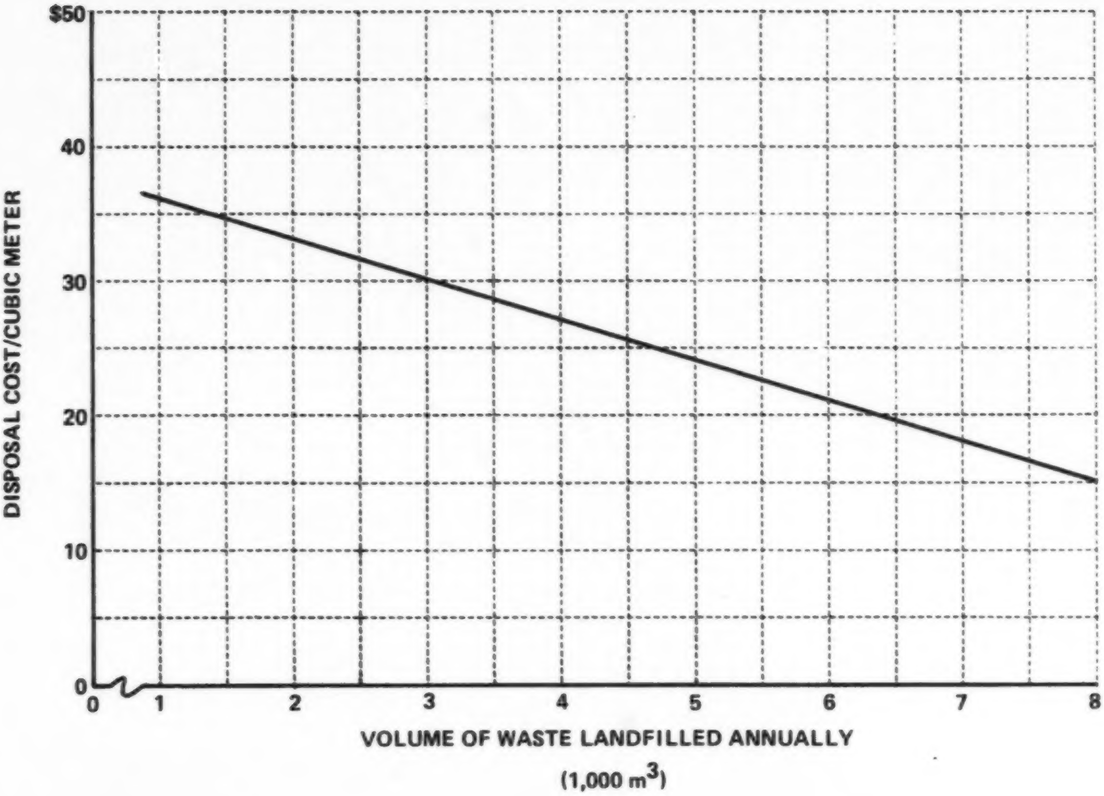

Figure 27. CHEMICAL LANDFILL COSTS

Operations. It is assumed that the annual amount of waste disposed is 1,000 m^3 (1,300 yd^3) and that the cover material equals 25 percent of the waste, i.e. 250 m^3 (325 yd^3). Thus, one trench is filled each year.

The total space required for 20 years of operations is 1.2 ha (3 acres).

A concrete sump is installed at each trench operation for leachate collection. A pump is provided to remove rain water from the trench during its operational life. The collected leachate is pumped from the sump to a trench currently in use.

Operations are conducted at the site 250 days per year. Three man-hours/day are allocated for the purpose of covering the dumped wastes, inspection and related activities.

Costs.

Land - The land acquisition cost is \$12,355/ha (\$5,000/acre). The cost of land needed for 20 years of operation is \$15,000. It is assumed that the land is purchased on the basis of a 20 year, 10 percent mortgage with no down payment. The annual payment then amounts to \$1,755. A total of \$35,000 is paid over the 20 year period. It is assumed that the initial land cost is recovered at the end of this period. The amount of interest paid is \$20,100. The average amount of interest paid per year is \$1,005 which value is used in the subsequent cost computations.

Trench Construction - Since it is assumed that one trench is filled each year, its cost is considered as an annual cost. Construction costs are computed as follows:

1.	Excavation 1,250 m^3 at $\$2.00/m^3$,[2]	\$2,500
2.	Grading 700 m^2 at $\$0.4/m^2$,[2]	300
3.	Survey, test boring, reports 20% of 1 & 2,[3]	600
4.	Bentonite liner 700 m^2 at $\$1.80\ m^2$,[4] *	1,300
5.	Hypalon liner 700 m^2 at $\$4.40/m^2$,[4]*	3,100
6.	Leachate collection drains 150 m at \$5.75/m[5]	900
7.	Clay protective liner 360 m^2 at $\$1/m^2$,[3]	400
8.	Finish bentonite liner 390 m^2 at $\$1.80/m^2$,[4]	700
9.	Concrete sump 1 x 1 x 1 m^3	250
	Total	10,050
	Contingency 20%	2,000
	Total Construction Cost	\$12,050

*Escalated from \$ 1974 to \$ 2nd Qtr. 1976 using M & S Equipment Cost Index \$1974 = 398.4; 2nd Qtr. 1976 = 478.5)

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Facilities - A temporary, reusable fence, similar to a snow fence, is erected around each active disposal site. The site perimeter is about 110 m. The fence cost is $7.20/lineal meter.[2]

Equipment - A crawler dozer is used for spreading and compacting the waste and cover material. Its estimated cost is $20,000.[3] A 1 hp sump pump is installed at an estimated cost of $1,600.[2]

Operations and Maintenance

Capital Recovery - Facilities and equipment are amortized over a 10 year period. A 10 percent interest rate is assumed.

Operating Personnel - Personnel costs, including supervision and overhead are computed at $13.50/hr.

Maintenance - Maintenance costs of facilities and equipment are computed as 4 percent of capital cost.

Waste Transport - The loading, transport and dumping of the waste at the disposal site is estimated at $\$5/\text{m}^3$ of waste.

Taxes and Insurance - These costs are included as 4 percent of land, facility and equipment costs.

Energy - The crawler dozer is operated on the average of two hours per day and consumes 15 liters (4 gal.) of diesel fuel/hr. The cost of fuel is calculated as $0.13/l ($0.50/gal.). Electrical power cost for miscellaneous lighting is assumed to be 15 percent of the fuel cost.

Chemical Landfill Costs. Capital and annual costs for the operation, based on the aforementioned factors, are as follows:

Capital Cost

Land		$15,000
Facilities		800
Equipment		
Dozer	$20,000	
Pump Installed 1 hp	1,600	21,600
Total		$37,400
Contingency (Equipment and Facilities)		4,500
Total Capital Investment		$41,900

Annual Cost

Land		$ 1,010
Capital Recovery		4,380
Operations and Maintenance		
Trench construction	$12,050	
Operating personnel	10,130	
Maintenance	900	
Waste Transport	5,000	
Taxes and Insurance	1,680	29,760
Energy		
Fuel	1,000	
Electricity	150	1,150
	Total Annual Cost	$36,300

The annual cost ot $36,300 represents a unit cost of about $36/m^3 of waste disposed. The specific gravity of the waste is estimated to range from 0.8 to 0.2. Disposal costs expressed in terms of unit weight are:

Specific Gravity	Disposal Cost/Metric Ton
0.8	$45
1.0	36
1.2	30

Landfill Design No. 2 (6,000 m^3 of waste)

This landfill is designed to accommodate 6,000 m^3 of waste. The initial trench excavation totals 7,500 m^3. Except where specifically noted, the cost factors and methodology employed are the same as in the previous computation.

Pertinent parameters for this landfill are:

Width: Bottom 22.7 m Top 28.7 m
Length: Bottom 45.7 m Top 51.4 m
Depth: 6 m
Surface Area: 2,380 m^2
Area Occupied/trench: 2,000 m^2
Area required for 20 years: 4 ha (9.9 acres)

Trench Construction Cost

Excavation	$15,000
Grading	1,000
Survey, test boring, reports	3,200
Bentonite liner	4,300
Hypalon liner	10,500
Leachate collection drain	3,100
Clay protective liner	1,200
Finish bentonite liner	2,660
Concrete sump 2 x 1 x 1 m	400
Total	$41,360
Contingency	8,270
Total Construction Cost	$49,630

Capital and annual cost factors which differ from the previous calculations are as follows:

Dozer cost	$30,000
Pump	2,400
Fencing	190 m
Dozer fuel consumption	19 l (5 gal)/hr.
Operating personnel	8 hr/day

Capital Cost

Land		$49,500
Facilities		1,400
Equipment		
Dozer	$30,000	
Pump Installed 2½ hp	2,400	32,400
Total		$83,300
Contingency (Equipment and Facilities)		6,800
Total Capital Investment		$90,100

Annual Cost

Land		$3,320
Capital Recovery		6,600
Operations and Maintenance		
Trench construction	$49,630	
Operating personnel	27,000	
Maintenance	1,350	
Waste transport	30,000	
Taxes and insurance	3,600	111,580
Energy		
Fuel	5,000	
Electricity	750	5,750
Total Annual Cost		$127,250

This annual cost results in a cost/metric ton of waste of about $21. Disposal costs as a function of weight are:

Specific Gravity	Disposal Cost/Metric Ton
0.8	$26
1.0	21
1.2	18

Disposal costs are sensitive to the size of the operation and the specific gravity of the material being landfilled. The chemical landfill costs are based on the volume of waste landfilled as presented in Figure 27. The disposal cost for plants with an annual volume of waste of less than 1,000 m^3 are based on a 1,000 m^3 landfill operation; costs for plants generating more than 8,000 m^3 of waste annually are based on an 8,000 m^3 landfill operation.

SECTION II

SANITARY LANDFILL COST DEVELOPMENT

Costs are based on the same parameters, cost factors, and methodology that are used for estimating the chemical or secure landfill costs except that liner, leachate collection system, sump and pump costs are deleted. A sanitary landfill cost curve (Figure 28) was developed from landfill designs for 1,000 and 6,000 m^3 of waste disposed annually as shown following.

Landfill Design No. 1 (1,000 m^3 of waste)

The following costs are based on a landfill volume of 1,000 m^3 of waste.

Trench Construction Cost	
1. Excavation 1,250 m^3 at \$2.00/m^3	$2,500
2. Grading 700 m^2 at \$0.4/m^2	300
3. Survey, test boring, reports 20% of 1 & 2	600
Total	$3,400
Contingency	700
Total Construction Costs	$4,100

Capital and Annual costs are as follows:

Capital Cost	
Land	$15,000
Facilities	800
Equipment	20,000
Total	$35,800
Contingency (Equipment & Facilities)	4,200
Total Capital Investment	$40,000

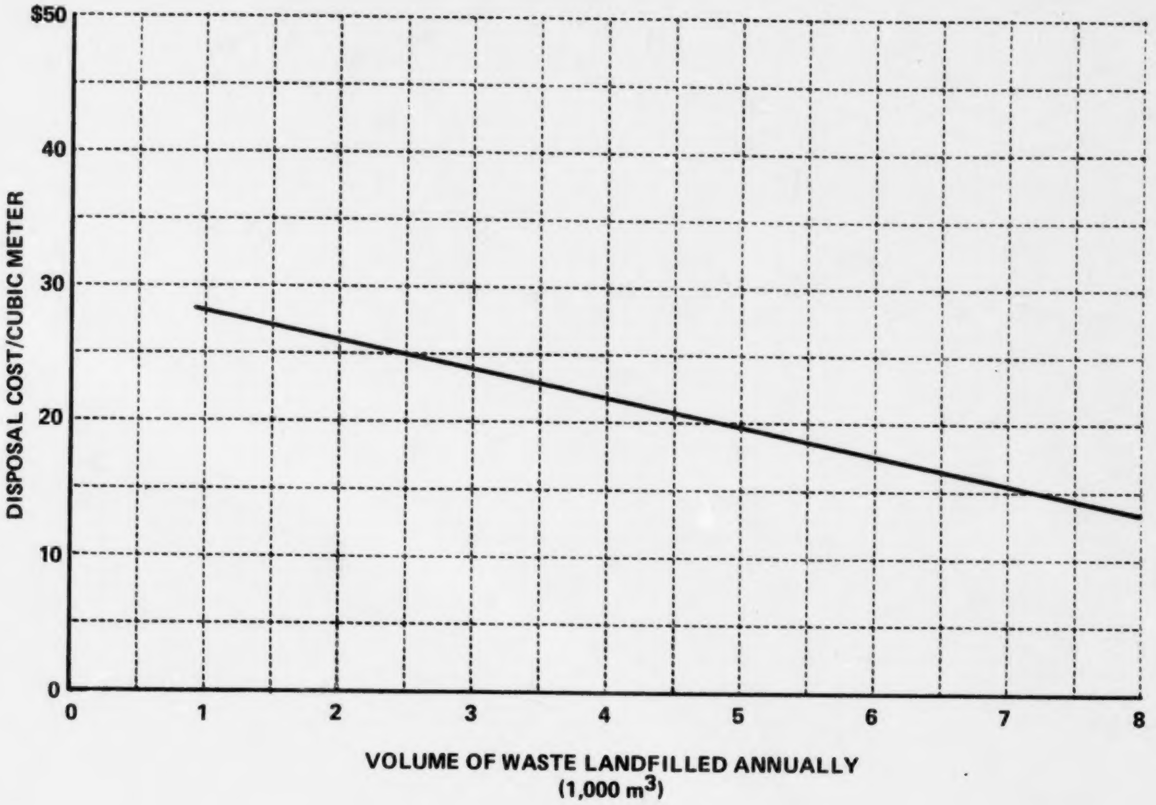

Figure 28. SANITARY LANDFILL COSTS

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Annual Cost

Land		**$1,010**
Capital Recovery		**4,080**
Operations and Maintenance		
Trench Construction	**$4,100**	
Operating Personnel	**10,130**	
Maintenance	**830**	
Waste Transport	**5,000**	
Taxes and Insurance	**1,600**	**21,660**
Energy		
Fuel	**1,000**	
Electricity	**100**	**1,100**
	Total Annual Cost	**$27,850**

The annual cost of $27,850 represents a unit cost of about $\$28/m^3$ of waste disposed. The specific gravity of the waste is estimated to range from 0.8 to 1.2. Disposal costs expressed in terms of unit weight are:

Specific Gravity	Disposal Cost/Metric Ton
0.8	$35
1.0	28
1.2	23

Landfill Design No. 2 (6,000 m^3 of waste)

These costs are based on a landfill volume of 6,000 m^3 of waste.

Trench Construction Cost

1. Excavation	$15,000
2. Grading	1,000
3. Survey, test boring, reports	3,200
Total	$19,200
Contingency	3,800
Total Construction Cost	$23,000

Capital and annual costs are as follows:

Capital Cost

Land	$49,500
Facilities	1,400
Equipment	30,000
Total	$80,900
Contingency	6,300
Total Capital Investment	$87,200

Annual Cost

Land		$3,320
Capital Recovery		6,150
Operations and Maintenance		
Trench Construction	$23,000	
Operating Personnel	27,000	
Maintenance	1,260	
Waste Transport	30,000	
Taxes and Insurance	3,490	84,750
Energy		
Fuel	5,000	
Electricity	500	5,500
Total Annual Cost		$99,720

This annual cost results in a cost/metric ton of waste of about $17. Disposal costs as a function of weight are:

Specific Gravity	Disposal Cost/Metric Ton
0.8	$21
1.0	17
1.2	14

Disposal costs are sensitive to the size of the operation and the specific gravity of the material being landfilled. The sanitary landfill costs are based on the volume of waste deposited as presented in Figure 28. The disposal cost for plants, with an annual volume of waste of less than 1,000 m^3 are based on an 1,000 m^3 landfill operation; costs for plants generating more than 8,000 m^3 of waste annually are based on an 8,000 m^3 landfill operation.

Waste Containerization. Liquid and semi-liquid wastes are containerized in 0.2 m^3 (55 gal.) drums for either chemical or sanitary landfills. The added cost of containerization is estimated to be $12.50 per drum. This cost includes the container and the labor for filling the container. Containerization costs are included in subsequent tables as noted.

SECTION III

SANITARY AND CHEMICAL LANDFILL COSTS

Costs are presented for the sanitary and chemical landfill disposal of wastes. The costs are shown for sanitary landfill without containerization of liquid wastes in Table 41; sanitary landfill with containerization of liquid wastes in Table 42; and for chemical landfill with containerization of liquid wastes in Table 43.

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Table 41 Summary of Costs for Sanitary Landfill Disposal Without Sludge Containerization

Waste Stream	Number	Sanitary Landfill Without Containerization $/Metric Ton of Waste		$/Metric Ton of Product
		Wet Basis	Dry Basis	
Iron and Steel Coke Production - Ammonia Still Lime Sludge	1	$ 21.48	$ 70.57	$ 0.02
Iron and Steel Coke Production - Decanter Tank Tar from Coke Production	2	10.42	52.27	0.12
Iron and Steel Prod. - Basic Oxygen Furnace - Wet Emission Control Unit Sludge	3	6.26	15.64	0.27
Iron and Steel Prod. - Open Hearth Furnace - Emission Control Dust	4	--	13.33	0.18
Iron and Steel Prod. - Electric Furnace - Wet Emission Control Sludge	5	9.17	22.70	0.20
Iron and Steel Prod. - Rolling Mill Sludge	6	12.25	30.82	0.05
Iron and Steel Prod. - Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	7A	21.00	84.00	0.01

Table 41 Summary of Costs for Sanitary Landfill Disposal Without Sludge Containerization (Cont.)

Waste Stream	Number	Sanitary Landfill Without Containerization $/Metric Ton of Waste Wet Basis	Sanitary Landfill Without Containerization $/Metric Ton of Waste Dry Basis	$/Metric Ton of Product
Iron and Steel Prod. - Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (HCl)	7B	$ 28.00	$ 280.00	$ 0.01
Iron and Steel Prod. - Cold Rolling Mill - Waste Pickle Liquor - Sulfuric Acid (H_2SO_4)	8A	11.36	279.30	1.28
Iron and Steel Prod. - Cold Rolling Mill - Waste Pickle Liquor - Hydrochloric Acid (HCl)	8B	11.33	132.81	0.61
Iron and Steel Prod. - Galvanizing Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	9A	14.93	48.00	0.54
Iron and Steel Prod. - Galvanizing Mill - Acid Rinsewater Neutralization Sludge (HCl)	9B	25.20	84.00	0.20
Ferroalloys - Ferrosilicon Manufacture - Miscellaneous Dusts	11	--	8.33	2.81
Ferroalloys - Ferrosilicon Manufacture - Slag	12A	--	7.34	12.86

Table 41 Summary of Costs for Sanitary Landfill Disposal Without Sludge Containerization (Cont.)

Waste Stream	Number	Sanitary Landfill Without Containerization $/Metric Ton of Waste Wet Basis	Sanitary Landfill Without Containerization $/Metric Ton of Waste Dry Basis	$/Metric Ton of Product
Ferroalloys - Ferrosilicon Manufacture - Dust	12B	$ --	$ 8.25	$ 1.25
Ferroalloys - Ferrosilicon Manufacture - Sludge	12C	10.42	25.94	3.93
Ferroalloys - Silicomanganese Manufacture - Slag and Scrubber Sludge	13	--	7.36	8.09
Ferroalloys - Ferromanganese Manufacture - Slag and Sludge	14	8.95	22.33	6.63
Copper Smelting - Acid Plant Blowdown Sludge	15	24.00	56.00	0.17
Electrolytic Copper Refining - Mixed Sludge	16	17.82	49.00	0.12
Lead Smelting - Sludge	17	10.42	34.62	2.05
Electrolytic Zinc Manufacture	18	11.94	39.94	1.04
Pyrometallurgical Zinc Manufacture - Sludges - Primary Gas Cleaning and Acid Plant Blowdown	19A	9.62	31.83	3.87

Table 41 Summary of Costs for Sanitary Landfill Disposal Without Sludge Containerization (Cont.)

Waste Stream	Number	Sanitary Landfill Without Containerization $/Metric Ton of Waste Wet Basis	Sanitary Landfill Without Containerization $/Metric Ton of Waste Dry Basis	$/Metric Ton of Product
Pyrometallurgical Zinc Manufacture - Sludges - Retort Gas Scrubber Bleed	19B	$ 15.00	$ 30.00	$ 0.31
Aluminum Manufacture - Scrubber Sludges	20	8.70	28.91	3.38
Aluminum Manufacture - Spent Potliners and Skimmings	21	--	9.04	0.53
Aluminum Manufacture - Shot Blast and Cast House Dusts	22	--	25.45	0.18
Pyrometallurgical Antimony Manufacture-Blast Furnace Slag	23	--	10.86	30.96
Electrolytic Antimony Manufacture - Spent Anolyte Sludge	24	21.00	63.00	14.00
Titanium Manufacture-Chlorinator Condenser Sludge	25	15.68	39.52	13.00
Copper Refining Blast Furnace Slag	27	--	13.63	4.77
Lead Refining - SO_2 Scrubwater Sludge	28	22.92	76.39	3.44

Table 41 Summary of Costs for Sanitary Landfill Disposal Without Sludge Containerization (Cont.)

Waste Stream	Number	Sanitary Landfill Without Containerization $/Metric Ton of Waste Wet Basis	Sanitary Landfill Without Containerization $/Metric Ton of Waste Dry Basis	$/Metric Ton of Product
Aluminum Refining - Scrubber Sludge	29	$ 12.25	$ 40.83	$ 3.06
Aluminum Refining - High Salt Slag	30	--	7.50	10.50

Table 42 Summary of Costs for Sanitary Landfill Disposal with Sludge Containerization

		Sanitary Landfill With Containerization $/Metric Ton of Waste		
Waste Stream	Number	Wet Basis	Dry Basis	$/Metric Ton of Product
Iron and Steel Coke Production - Ammonia Still Lime Sludge	1	$ 73.11	$ 240.21	$ 0.07
Iron and Steel Coke Production - Decanter Tank Tar from Coke Prod.	2	62.50	313.64	0.69
Iron and Steel Production - Basic Oxygen Furnace - Wet Emission Control Unit Sludge	3	37.54	93.85	1.62
Iron and Steel Production - Open Hearth Furnace - Emission Control Dust	4	--	13.33*	0.18
Iron and Steel Production - Electric Furnace - Wet Emission Control Sludge	5	40.13	99.41	0.87
Iron and Steel Production - Rolling Mill Sludge	6	51.51	129.61	0.22
Iron and Steel Production - Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	7A	67.88	271.50	0.04

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*Same cost as without containerization because waste is dry. (See Table 41)

Table 42 Summary of Costs for Sanitary Landfill Disposal with Sludge Containerization (Cont.)

Waste Stream	Number	Sanitary Landfill With Containerization $/Metric Ton of Waste Wet Basis	Dry Basis	$/Metric Ton of Product
Iron and Steel Production - Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (HCl)	7B	$ 90.50	$ 905.00	$ 0.04
Iron and Steel Production - Cold Rolling Mill - Waste Pickle Liquor - Sulfuric Acid (H_2SO_4)	8A	68.14	1,675.78	7.66
Iron and Steel Production - Cold Rolling Mill - Waste Pickle Liquor - Hydrochloric Acid (HCl)	8B	68.00	796.88	3.64
Iron and Steel Production - Galvanizing Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	9A	53.82	173.00	1.94
Iron and Steel Production - Galvanizing Mill - Acid Rinsewater Neutralization Sludge (HCl)	9B	81.45	271.50	0.65
Ferroalloys - Ferrosilicon Manufacture - Miscellaneous Dusts	11	--	8.33*	2.81
Ferroalloys - Ferrosilicon Manufacture - Slag	12A	--	7.34*	12.86

*Same cost as without containerization because waste is dry. (See Table 41)

Table 42 Summary of Costs for Sanitary Landfill Disposal with Sludge Containerization (Cont.)

Waste Stream	Number	Sanitary Landfill With Containerization $/Metric Ton of Waste Wet Basis	Sanitary Landfill With Containerization $/Metric Ton of Waste Dry Basis	$/Metric Ton of Product
Ferroalloys - Ferrosilicon Manufacture - Dust	12B	$ --	$ 8.25*	$ 1.25
Ferroalloys - Ferrosilicon Manufacture - Sludge	12C	62.50	155.66	23.57
Ferroalloys - Silicomanganese Manufacture - Slag and Scrubber Sludge	13	--	7.36*	8.09
Ferroalloys - Ferromanganese Manufacture - Slag and Sludge	14	53.72	133.99	39.75
Copper Smelting - Acid Plant Blowdown Sludge	15	77.57	181.00	0.54
Electrolytic Copper Refining - Mixed Sludge	16	57.59	158.38	0.40
Lead Smelting - Sludge	17	62.50	207.69	12.27
Electrolytic Zinc Manufacture	18	60.07	201.00	5.23
Pyrometallurgical Zinc Manufacture - Sludges - Primary Gas Cleaning and Acid Plant Blowdown	19A	57.73	190.96	23.20

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*Same cost as without containerization because waste is dry. (See Table 41)

Table 42 Summary of Costs for Sanitary Landfill Disposal with Sludge Containerization (Cont.)

Waste Stream	Number	Sanitary Landfill With Containerization $/Metric Ton of Waste Wet Basis	Dry Basis	$/Metric Ton of Product
Pyrometallurgical Zinc Manufacture Sludges - Retort Gas Scrubber Bleed	19B	$ 49.09	$ 98.18	$ 1.01
Aluminum Manufacture - Scrubber Sludges	20	52.18	173.46	20.29
Aluminum Manufacture - Spent Potliners and Skimmings	21	--	9.04*	0.53
Aluminum Manufacture - Shot Blast and Cast House Dusts	22	--	25.45*	0.18
Pyrometallurgical Antimony Manufacture - Blast Furnace Slag	23	--	10.86*	30.96
Electrolytic Antimony Manufacture-Spent Anolyte Sludge	24	67.88	203.63	45.25
Titanium Manufacture - Chlorinator Condenser Sludge	25	67.27	169.52	55.76
Copper Refining - Blast Furnace Slag	27	--	13.63	4.77
Lead Refining - SO_2 Scrubwater Sludge	28	75.00	250.00	11.25

*Same cost as without containerization because waste is dry. (See Table 41)

Table 42 Summary of Costs for Sanitary Landfill Disposal with Sludge Containerization (Cont.)

Waste Stream	Number	Sanitary Landfill With Containerization $/Metric Ton of Waste Wet Basis	Sanitary Landfill With Containerization $/Metric Ton of Waste Dry Basis	$/Metric Ton of Product
Aluminum Refining - Scrubber Sludge	29	$ 43.50	$ 145.00	$10.88
Aluminum Refining - High Salt Slag	30	--	7.50*	10.50

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*Same cost as without containerization because waste is dry. (See Table 41)

Table 43 Summary of Costs for Chemical Landfill Disposal With Sludge Containerization

Waste Stream	Number	Chemical Landfill With Containerization* $/Metric Ton of Waste Wet Basis	Dry Basis	$/Metric Ton of Product
Iron and Steel Coke Production - Ammonia Still Lime Sludge	1	$78.89	$ 259.21	$ 0.07
Iron and Steel Coke Production - Decanter Tank Tar from Coke Prod.	2	64.58	324.09	0.71
Iron and Steel Production - Basic Oxygen Furnace - Wet Emission Control Unit Sludge	3	38.79	96.99	1.68
Iron and Steel Production - Open Hearth Furnace - Emission Control Dust	4	--	16.67	0.23
Iron and Steel Production - Electric Furnace - Wet Emission Control Sludge	5	42.11	104.32	0.92
Iron and Steel Production - Rolling Mill Sludge	6	54.34	136.73	0.24
Iron and Steel Production - Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	7A	73.88	295.00	0.04

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* Only for liquid and semi-liquid wastes.

Table 43 Summary of Costs for Chemical Landfill Disposal with Sludge Containerization (Cont.)

Waste Stream	Number	Chemical Landfill With Containerization* $/Metric Ton of Waste Wet Basis	Chemical Landfill With Containerization* $/Metric Ton of Waste Dry Basis	$/Metric Ton of Product
Iron and Steel Production - Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (HCl)	7B	$98.50	$ 985.00	$ 0.04
Iron and Steel Production - Cold Rolling Mill - Waste Pickle Liquor - Sulfuric Acid (H_2SO_4)	8A	70.41	1,731.64	7.92
Iron and Steel Production - Cold Rolling Mill - Waste Pickle Liquor - Hydrochloric Acid (HCl)	8B	70.27	823.44	3.76
Iron and Steel Production - Galvanizing Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	9A	57.87	186.00	2.08
Iron and Steel Production - Galvanizing Mill - Acid Rinsewater Neutralization Sludge (HCl)	9B	88.65	295.50	0.71
Ferroalloys - Ferrosilicon Manufacture - Miscellaneous Dusts	11	--	10.00	3.38
Ferroalloys - Ferrosilicon Manufacture - Slag	12A	--	8.81	15.42

* Only for liquid and semi-liquid wastes.

Table 43 Summary of Costs for Chemical Landfill Disposal with Sludge Containerization (Cont.)

Waste Stream	Number	Chemical Landfill With Containerization* $/Metric Ton of Waste Wet Basis	Chemical Landfill With Containerization* $/Metric Ton of Waste Dry Basis	$/Metric Ton of Product
Ferroalloys - Ferrosilicon Manufacture - Dust	12B	$ --	$ 9.91	$ 1.50
Ferroalloys - Ferrosilicon Manufacture - Sludge	12C	64.58	160.85	24.36
Ferroalloys - Silicomanganese Manufacture - Slag and Scrubber Sludge	13	--	8.83	9.71
Ferroalloys - Ferromanganese Manufacture - Slag and Sludge	14	55.51	138.46	41.01
Copper Smelting - Acid Plant Blowdown Sludge	15	84.43	197.00	0.59
Electrolytic Copper Refining - Mixed Sludge	16	62.68	172.38	0.43
Lead Smelting - Sludge	17	64.58	214.62	12.68
Electrolytic Zinc Manufacture	18	62.38	208.73	5.43
Pyrometallurgical Zinc Manufacture - Sludges - Primary Gas Cleaning and Acid Plant Blowdown	19A	59.66	197.33	23.97

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* Only for liquid and semi-liquid wastes.

Table 43 Summary of Costs for Chemical Landfill Disposal with Sludge Containerization (Cont.)

Waste Stream	Number	Chemical Landfill With Containerization* $/Metric Ton of Waste Wet Basis	Chemical Landfill With Containerization* $/Metric Ton of Waste Dry Basis	$/Metric Ton of Product
Pyrometallurgical Zinc Manufacture Sludges - Retort Gas Scrubber Bleed	19B	$53.45	$ 106.91	$ 1.10
Aluminum Manufacture - Scrubber Sludges	20	53.93	179.25	20.97
Aluminum Manufacture - Spent Potliners and Skimmings	21	--	11.51	0.68
Aluminum Manufacture - Shot Blast and Cast House Dusts	22	--	32.73	0.24
Pyrometallurgical Antimony Manufacture - Blast Furnace Slag	23	--	13.57	38.70
Electrolytic Antimony Manufacture-Spent Anolyte Sludge	24	73.88	221.63	49.25
Titanium Manufacture - Chlorinator Condenser Sludge	25	70.98	178.88	58.84
Copper Refining - Blast Furnace Slag	27	--	17.23	6.03
Lead Refining - SO_2 Scrubwater Sludge	28	81.25	270.83	12.19

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* Only for liquid and semi-liquid wastes.

Table 43 Summary of Costs for Chemical Landfill Disposal with Sludge Containerization (Cont.)

Waste Stream	Number	Chemical Landfill With Containerization* $/Metric Ton of Waste Wet Basis	Chemical Landfill With Containerization* $/Metric Ton of Waste Dry Basis	$/Metric Ton of Product
Aluminum Refining - Scrubber Sludge	29	$ 47.00	$ 156.67	$11.75
Aluminum Refining - High Salt Slag	30	--	9.00	12.60

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* Only for liquid and semi-liquid wastes.

REFERENCES

PART II

(1) Letter to Mr. E. Isenberg from Alexandra G. Tarnay, Hazardous Waste Management Division (AW-465), 20 October 1976.

(2) "Building Construction Cost Data 1976," Robert Snow Means Co., Inc.

(3) Calspan estimate

(4) "Liners for Land Disposal Sites, an Assessment," EPA/530/SW-137, March 1975

(5) Vendor Information

PART III

COMPARISON OF LANDFILL COSTS WITH ALTERNATIVE TREATMENT COSTS

A. Comparison of Landfill and Alternative Treatment Costs

The costs for alternative treatment processes and landfill are shown in Table 44. The costs are relative and are expressed as ratios with the cost of sanitary landfill without containerization used as the denominator. The comparison is made in terms of cost permetric ton of product. The lowest cost alternative is designated for each waste.

As would be expected, the costs of sanitary landfill with containerization and chemical landfill are always higher than sanitary landfill without containerization costs. In two cases, Waste Nos. 1 and 7, the sanitary landfill cost with containerization is the same as the chemical landfill cost. These cases are characterized by large annual productions and relatively small quantities of wastes. Containerization represents the dominant cost.

Sanitary landfill is the least cost alternative for 15 wastes when liquids are not containerized.

Chemical landfilling because of the requirement to containerize liquid wastes and its inherent higher costs does not provide any least cost waste candidates.

Alternative treatment processes excluding recovery values (total), offer least costs for six of the wastes with one of these, pyrometallurgical zinc retort gas scrubber bleed, waste stream 19, at par with sanitary landfilling without containerization.

Alternative treatment processes, where recovery values were included (net) offer least cost possibilities for eight of the wastes.

Table 45 is a tabulation of the actual costs that were used to calculate the relative costs shown in Table 44.

Table 44 Relative Costs for Landfill and Alternative Treatment Process (Per Unit of Product)

Waste Stream	Number	Sanitary Landfill W/O Contain.	Sanitary Landfill With Contain.	Chemical Landfill	Alternative Treatment Process	
					Total	Net
Iron and Steel Coke Production - Ammonia Still Lime Sludge	1	1	3.50	3.50	3.5	NRV
Iron and Steel Coke Production - Decanter Tank Tar from Coke Production	2	1	5.75	5.92	35.5	NRV
Iron and Steel Production - Basic Oxygen Furnace - Wet Emission Control Unit Sludge	3	1	3.83	4.35	0.74	0.43
Iron and Steel Production - Open Hearth Furnace - Emission Control Dust	4	1	3.83	4.35	0.74	0.43
Iron and Steel Production - Electric Furnace - Wet Emission Control Sludge	5	1	3.83	4.35	0.74	0.43
Iron and Steel Production - Rolling Mill Sludge	6	1	4.40	4.80	0.60	0.12
Iron and Steel Production - Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	7A	1	4.00	4.00	0.40	NRV

See page 220 for legend.

Table 44 Relative Costs for Landfill and Alternative Treatment Process (Per Unit of Product) (Cont.)

Waste Stream	Number	Sanitary Landfill W/O Contain.	Sanitary Landfill With Contain.	Chemical Landfill	Alternative Treatment Process	
					Total	Net
Iron and Steel Production - Cold Rolling Mill - Acid Rinsewater Neutralization Sludge (HCl)	7B	1	4.00	4.00	0.30	NRV
Iron and Steel Production - Cold Rolling Mill - Waste Pickle Liquor - Sulfuric Acid (H_2SO_4)	8A	1	5.98	6.19	4.88	3.80
Iron and Steel Production - Cold Rolling Mill - Waste Pickle Liquor - Hydrochloric Acid (HCl)	8B	1	5.97	6.16	3.38	2.18
Iron and Steel Production - Galvanizing Mill - Acid Rinsewater Neutralization Sludge (H_2SO_4)	9A	1	3.59	3.85	0.07	NRV
Iron and Steel Production - Galvanizing Mill - Acid Rinsewater Neutralization Sludge (HCl)	9B	1	3.25	3.55	0.15	NRV
Ferroalloys - Ferrosilicon Manufacture - Miscellaneous Dusts	11	1	N.A.	1.20	1.91	NRV
Ferroalloys - Ferrosilicon Manufacture - Slag	12A	1	N.A.	1.20	0.53	0.40

See page 220 for legend.

Table 44 Relative Costs for Landfill and Alternative Treatment Process (Per Unit of Product) (Cont.)

Waste Stream	Number	Sanitary Landfill W/O Contain.	Sanitary Landfill With Contain.	Chemical Landfill	Alternative Treatment Process	
					Total	Net
Ferroalloys - Ferrosilicon Manufacture - Dust	12B	1	N.A.	1.20	2.28	NRV
Ferroalloys - Ferrosilicon Manufacture - Sludge	12C	1	6.00	6.20	1.33	NRV
Ferroalloys - Silicomanganese Manufacture - Slag and Scrubber Sludge	13	1	2.70	3.45	1.02	0.95
Ferroalloys - Ferromanganese Manufacture - Slag and Sludge	14	1	2.70	3.45	1.02	0.95
Copper Smelting - Acid Plant Blowdown Sludge	15	1	3.18	3.47	15.59	NRV
Electrolytic Copper Refining - Mixed Sludge	16	1	3.33	3.58	20.67	NRV
Lead Smelting - Sludge	17	1	5.99	6.19	0.65	*
Electrolytic Zinc Manufacture	18	1	5.03	5.22	1.40	*
Pyrometallurgical Zinc Manufacture - Sludges - Primary Gas Cleaning and Acid Plant Blowdown	19A	1	5.99	6.19	0.40	*

See page 220 for legend.

Table 44 Relative Costs for Landfill and Alternative Treatment Process (Per Unit of Product) (Cont.)

Waste Stream	Number	Sanitary Landfill W/O Contain.	Sanitary Landfill With Contain.	Chemical Landfill	Alternative Treatment Process	
					Total	Net
Pyrometallurgical Zinc Manufacture - Sludges - Retort Gas Scrubber Bleed	19B	1	3.26	3.55	1.00	NRV
Aluminum Manufacture - Scrubber Sludges	20	1	5.20	5.54	3.49	*
Aluminum Manufacture - Spent Potliners and Skimmings	21	1	5.20	5.54	3.49	*
Aluminum Manufacture - Shot Blast and Cast House Dusts	22	1	N.A.	1.33	3.00	NRV
Pyrometallurgical Antimony Manufacture - Blast Furnace Slag	23	1	N.A.	1.25	1.70	NRV
Electrolytic Antimony Manufacture-Spent Anolyte Sludge	24	1	3.23	3.52	2.62	NRV
Titanium Manufacture - Chlorinator Condenser Sludge	25	1	4.29	4.53	0.80	*
Copper Refining - Blast Furnace Slag	27	1	N.A.	1.26	2.78	NRV
Lead Refining - SO_2 Scrubwater Sludge	28	1	3.27	3.54	1.12	NRV

See page 220 for legend.

Table 44 Relative Costs for Landfill and Alternative Treatment Process (Per Unit of Product) (Cont.)

Waste Stream	Number	Sanitary Landfill W/O Contain.	Sanitary Landfill With Contain.	Chemical Landfill	Alternative Treatment Process	
					Total	Net
Aluminum Refining - Scrubber Sludge	29	1	3.56	3.84	1.36	NRV
Aluminum Refining - High Salt Slag	30	1	N.A.	1.20	6.38	3.47

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* = is used to denote that the alternative treatment process results in a net gain
___ = least cost alternative
N.A. = Not applicable
NRV = No recovery value

Table 45

COST SUMMARY FOR LANDFILL AND ALTERNATIVE TREATMENT PROCESSES[a]

($/METRIC TON)

WASTE STREAM	WASTE NO.	SANITARY LANDFILL						CHEMICAL LANDFILL			ALTERNATIVE TREATMENT					
		WITHOUT CONTAINERIZATION			WITH CONTAINERIZATION			WITH SLUDGE CONTAINERIZATION								
		WASTE		PRODUCT	WASTE		PRODUCT	WASTE		PRODUCT	WASTE				PRODUCT	
											WET		DRY			
		DRY BASIS	WET BASIS		DRY BASIS	WET BASIS		WET BASIS	DRY BASIS		TOTAL	NET	TOTAL	NET	TOTAL[b]	NET[c]
IRON AND STEEL COKE PRODUCTION - AMMONIA STILL LIME SLUDGE	1	21.48	70.27	0.02	73.11	240.21	0.07	78.89	259.21	0.07	78.89	NRV	259.21	NRV	0.07	NRV
IRON AND STEEL COKE PRODUCTION - DECANTER TANK TAR FROM COKE PRODUCTION	2	10.42	52.27	0.12	62.50	313.64	0.69	64.58	324.09	0.71	64.58	NRV	324.09	NRV	0.71	NRV
IRON AND STEEL PRODUCTION - BASIC OXYGEN FURNACE - WET EMISSION CONTROL UNIT SLUDGE	3	6.26	15.64	0.27	37.54	93.85	1.62	38.79	96.99	1.68	12.66	7.36	29.90	17.40	0.48	0.28
IRON AND STEEL PRODUCTION - OPEN HEARTH FURNACE - EMISSION CONTROL DUST	4	NRV	13.33	0.18	NRV	13.33	0.18	NRV	16.67	0.23	12.66	7.36	29.90	17.40	0.48	0.28
IRON AND STEEL PRODUCTION - ELECTRIC FURNACE - WET EMISSION CONTROL SLUDGE	5	9.17	22.70	0.20	40.13	99.41	0.87	42.11	104.32	0.92	12.66	7.36	29.90	17.40	0.48	0.28
IRON AND STEEL PRODUCTION - ROLLING MILL SLUDGE	6	12.25	30.82	0.05	51.51	129.61	0.22	54.34	136.73	0.24	6.46	1.45	16.25	3.65	0.03	0.006
IRON AND STEEL PRODUCTION - COLD ROLLING MILL - ACID RINSEWATER NEUTRALIZATION SLUDGE (H_2SO_4)	7A	21.00	84.00	0.01	67.88	271.50	0.04	73.88	295.50	0.04	6.85	NRV	27.40	NRV	0.004	NRV
IRON AND STEEL PRODUCTION - COLD ROLLING MILL - ACID RINSEWATER NEUTRALIZATION SLUDGE (HCl)	7B	28.00	280.00	0.01	90.50	905.00	0.04	98.50	985.00	0.04	6.77	NRV	67.67	NRV	0.003	NRV
IRON AND STEEL PRODUCTION - COLD ROLLING MILL - WASTE PICKLE LIQUOR - SULFURIC ACID (H_2SO_4)	8A	11.36	279.30	1.28	68.14	1675.78	7.66	70.41	1731.64	7.92	55.54	43.31	1365.82	1065.24	6.24	4.87

a = FOR A TYPICAL PLANT.
b = TOTAL DOES NOT INCLUDE RECOVERY VALUE.
c = NET INCLUDES RECOVERY VALUE.

N.A. = NOT APPLICABLE
* = NET GAIN FROM ALTERNATIVE TREATMENT PROCESS
NRV = NO RECOVERY VALUE

Table 45

COST SUMMARY FOR LANDFILL AND ALTERNATIVE TREATMENT PROCESSES[a] ($/METRIC TON) (Cont.)

WASTE STREAM	WASTE NO.	SANITARY LANDFILL						CHEMICAL LANDFILL			ALTERNATIVE TREATMENT					
		WITHOUT CONTAINERIZATION			WITH CONTAINERIZATION			WITH SLUDGE CONTAINERIZATION								
		WASTE		PRODUCT	WASTE		PRODUCT	WASTE		PRODUCT	WASTE				PRODUCT	
		DRY BASIS	WET BASIS		DRY BASIS	WET BASIS		WET BASIS	DRY BASIS		WET		DRY		TOTAL[b]	NET[c]
											TOTAL	NET	TOTAL	NET		
IRON AND STEEL PRODUCTION - COLD ROLLING MILL - WASTE PICKLE LIQUOR - HYDROCHLORIC ACID (HCl)	8B	11.33	132.81	0.61	68.00	796.88	3.64	70.27	823.44	3.76	38.38	24.80	449.78	290.63	2.06	1.33
IRON AND STEEL PRODUCTION - GALVANIZING MILL - ACID RINSE-WATER NEUTRALIZATION SLUDGE (H_2SO_4)	9A	14.93	48.00	0.54	53.82	173.00	1.94	57.87	186.00	2.08	0.99	NRV	3.19	NRV	0.04	NRV
IRON AND STEEL PRODUCTION - GALVANIZING MILL - ACID RINSE-WATER NEUTRALIZATION SLUDGE (HCl)	9B	25.20	84.00	0.20	81.45	271.50	0.65	88.65	295.50	0.71	3.74	NRV	12.47	NRV	0.03	NRV
FERROALLOYS - FERROSILICON MANUFACTURE - MISCELLANEOUS DUSTS	11	NRV	8.33	2.81	NRV	8.33	2.81	NRV	10.00	3.38	N.A.	N.A.	15.88	NRV	5.36	NRV
FERROALLOYS - FERROSILICON MANUFACTURE - SLAG	12A	NRV	7.34	12.86	NRV	7.34	12.86	NRV	8.81	15.42	N.A.	N.A.	3.91	2.91	6.85	5.10
FERROALLOYS - FERROSILICON MANUFACTURE - DUST	12B	NRV	8.25	1.25	NRV	8.25	1.25	NRV	9.91	1.50	N.A.	N.A.	18.82	NRV	2.85	NRV
FERROALLOYS - FERROSILICON MANUFACTURE - SLUDGE	12C	10.42	25.94	3.93	62.50	155.66	23.57	64.58	160.85	24.36	13.88	NRV	34.56	NRV	5.23	NRV
FERROALLOYS - SILICOMANGANESE MANUFACTURE - SLAG AND SCRUBBER SLUDGE	13	NRV	7.36	8.09	NRV	7.36	8.09	NRV	8.83	9.71	20.36	18.79	50.80	46.88	15.07	13.91
FERROALLOYS - FERROMANGANESE MANUFACTURE - SLAG AND SLUDGE	14	8.95	22.33	6.63	53.72	133.99	39.75	55.51	138.46	41.01	20.36	18.79	50.80	46.88	15.07	13.91
COPPER SMELTING - ACID PLANT BLOWDOWN SLUDGE	15	24.00	56.00	0.17	77.57	181.00	0.54	84.43	197.00	0.59	379.27	NRV	884.97	NRV	2.65	NRV
ELECTROLYTIC COPPER REFINING - MIXED SLUDGE	16	17.82	49.00	0.12	57.59	153.38	0.40	62.68	172.38	0.43	360.40	NRV	991.13	NRV	2.48	NRV

a = FOR A TYPICAL PLANT.
b = TOTAL DOES NOT INCLUDE RECOVERY VALUE.
c = NET INCLUDES RECOVERY VALUE.

N.A. = NOT APPLICABLE
* = NET GAIN FROM ALTERNATIVE TREATMENT PROCESS
NRV = NO RECOVERY VALUE

Table 45

COST SUMMARY FOR LANDFILL AND ALTERNATIVE TREATMENT PROCESSES[a] ($/METRIC TON) (Cont.)

WASTE STREAM	WASTE NO.	SANITARY LANDFILL						CHEMICAL LANDFILL			ALTERNATIVE TREATMENT					
		WITHOUT CONTAINERIZATION			WITH CONTAINERIZATION			WITH SLUDGE CONTAINERIZATION								
		WASTE		PRODUCT	WASTE		PRODUCT	WASTE		PRODUCT	WASTE				PRODUCT	
											WET		DRY			
		DRY BASIS	WET BASIS		DRY BASIS	WET BASIS		WET BASIS	DRY BASIS		TOTAL	NET	TOTAL	NET	TOTAL[b]	NET[c]
LEAD SMELTING - SLUDGE	17	10.42	34.62	2.05	62.50	207.69	12.27	64.58	214.62	12.68	6.80	1.01*	22.61	3.36*	1.34	0.20*
ELECTROLYTIC ZINC MANUFACTURE SLUDGE	18	11.94	39.94	1.04	60.07	201.00	5.23	62.38	208.73	5.43	16.81	3.50*	56.25	11.20*	1.46	0.29*
PYROMETALLURGICAL ZINC MANUFACTURE - SLUDGES - PRIMARY GAS CLEANING AND ACID PLANT BLOWDOWN	19A	9.62	31.83	3.87	57.73	190.96	23.20	59.66	197.33	23.97	3.56	15.44*	11.78	51.08*	1.43	6.21*
PYROMETALLURGICAL ZINC MANUFACTURE - SLUDGES - RETORT GAS SCRUBBER BLEED	19B	15.00	30.00	0.31	49.09	98.18	1.01	53.45	106.91	1.10	15.30	NRV	30.59	NRV	0.31	NRV
ALUMINUM MANUFACTURE SCRUBBER SLUDGES	20	8.70	28.91	3.38	52.18	173.46	20.29	53.92	179.25	20.97	35.09	18.36*	27.63	40.59*	13.86	7.14*
ALUMINUM MANUFACTURE - SPENT POTLINERS AND SKIMMINGS	21	NRV	9.04	0.53	NRV	9.04	0.53	NRV	11.51	0.68	35.09	18.36*	27.63	40.59*	13.86	7.14*
ALUMINUM MANUFACTURE - SHOT BLAST AND CAST HOUSE DUSTS	22	NRV	25.45	0.18	NRV	25.45	0.18	NRV	32.73	0.24	N.A.	N.A.	75.33	NRV	0.64	NRV
PYROMETALLURGICAL ANTIMONY MANUFACTURE - BLAST FURNACE SLAG	23	NRV	10.86	30.96	NRV	10.86	30.96	NRV	13.57	38.70	N.A.	N.A.	18.40	NRV	52.48	NRV
ELECTROLYTIC ANTIMONY MANUFACTURE - SPENT ANOLYTE SLUDGE	24	21.00	63.00	14.00	67.88	203.63	46.25	73.88	221.63	49.25	55.06	NRV	165.15	NRV	36.70	NRV
TITANIUM MANUFACTURE - CHLORINATOR CONDENSER SLUDGE	25	15.68	39.52	13.00	67.27	169.52	55.76	70.98	178.88	58.84	12.53	14.36*	31.59	37.41*	10.39	12.31*
COPPER REFINING - BLAST FURNACE SLAG	27	NRV	13.63	4.77	NRV	13.63	4.77	NRV	17.23	6.03	N.A.	N.A.	37.86	NRV	13.25	NRV
LEAD REFINING - SO_2 SCRUBWATER SLUDGE	28	22.92	76.39	3.44	75.00	250.00	11.25	81.25	270.83	12.19	25.61	NRV	85.36	NRV	3.84	NRV
ALUMINUM REFINING - SCRUBBER SLUDGE	29	12.25	40.83	3.06	43.50	145.00	10.88	47.00	156.67	11.75	16.59	NRV	56.29	NRV	4.15	NRV
ALUMINUM REFINING - HIGH SALT SLAG	30	NRV	7.50	10.50	NRV	7.50	10.50	NRV	9.00	12.80	N.A.	N.A.	47.89	26.02	67.04	36.43

a = FOR A TYPICAL PLANT.
b = TOTAL DOES NOT INCLUDE RECOVERY VALUE.
c = NET INCLUDES RECOVERY VALUE.

N.A. = NOT APPLICABLE
* = NET GAIN FROM ALTERNATIVE TREATMENT PROCESS
NRV = NO RECOVERY VALUE

APPENDIX A

COST DATA BASE

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Cost Data Base. The costs, cost factors and costing methodology used to derive the capital and annual costs are documented in this section. All costs are expressed in 1976 dollars.

The following categorization is used to present the costs:

Capital Cost
  - Facilities
  - Equipment
  - Installation
  - Contingency and Contractor's Fee

Annual Cost
  - Amortization
  - Operations and Maintenance
    - Operating Personnel
    - Repair and Maintenance
    - Materials
    - Waste Disposal
    - Taxes and Insurance
  - Energy

Capital Cost. The requirements for the alternative treatment processes cover a broad range of facilities, equipment and activities. In many instances, the alternative process entail the installation of a small or moderate amount of equipment, which, it is assumed, can be incorporated into existing plant operations. Some processes, however, require extensive facilities and equipment equivalent to an entirely new plant.

The capital cost of a new plant is based on gross equipment or total facility costs provided by A.D. Little and firms which have constructed similar operating facilities in recent years. An example is the Dravo-Lurgi HCl Regeneration Plant, for which the capital cost and operating requirements were provided by the Dravo Corporation. In the cases where only gross, installed equipment cost were available, the facility costs were estimated to be equal to the cost of the installed equipment. Such costs can vary considerably depending on the availability of suitable buildings, access roads, railway sidings and utilities.

Itemized costs are presented for the small and moderate-size operations. Parametric costs were developed for items which are common to many of the alternative processes; e.g. tanks, pumps and centrifuges. These and other equipment costs are based on vendor quotations. The parametric and other cost-estimating relationships employed are discussed below.

Sumps. Concrete pits sized to contain a 24-hour flow of wastewater are included with some treatment processes. In addition, concrete sludge-holding pits are provided, generally designed to hold a 7-day supply of sludge.

The pits are constructed of 20-centimeter (8 inch) reinforced base slabs and 40 centimeter (16 inch) walls. A general cost-estimating relationship was developed from a base slab cost of \$20/square meter (\$2/square foot) and a wall cost of \$300/cubic meter (\$8/cubic foot) of concrete in place. The costs include setup and layout, excavation, concrete, backfill and cleanup.[1]

For example, the cost of a 6 cubic meter (212 square foot) pit, measuring 3m x 2 m x 1 m (9.8 ft x 6.6 ft x 3.3 ft) is computer as follows: (3 x 2 x \$20) + (2 x 3 x 1 x 0.4 x \$300) + (2 x 2 x 1 x 0.4 x \$300) = \$1,320

Centrifuges. Costs, as a function of weight of sludge generated per day, are shown in Figure A-1. Power requirements for the size of centrifuges shown range from 10 to 40.0 hp. The curve given in Figure A-1 should not be extended beyond the lowest point shown, since this point represents the smallest sized centrifuge manufactured. Costs are based on equipment-manufacturer quotations. Centrifuges are selected for operating 12 hours or less per day.

Holding Tanks. Costs, based on vendor quotations, are shown in Figure A-2, as a function of capacity for steel and fiberglass polyester tanks.

Mixing Tanks. Mixing tank costs are shown in Figure A-3. The tanks are of steel construction and include agitators and motors. Costs are based on a vendor quotation.

Pumps. Pump costs, including motors, are shown in Figures A-4 and A-5 as a function of capacity expressed in liters (0.264 gal) per minute. The types and sizes of pumps required for a particular activity can vary widely, depending on the characteristics of the material being pumped and the height and distance of transport. The curves in Figures A-4 and A-5 represent costs for centrifugal and slurry pumps.

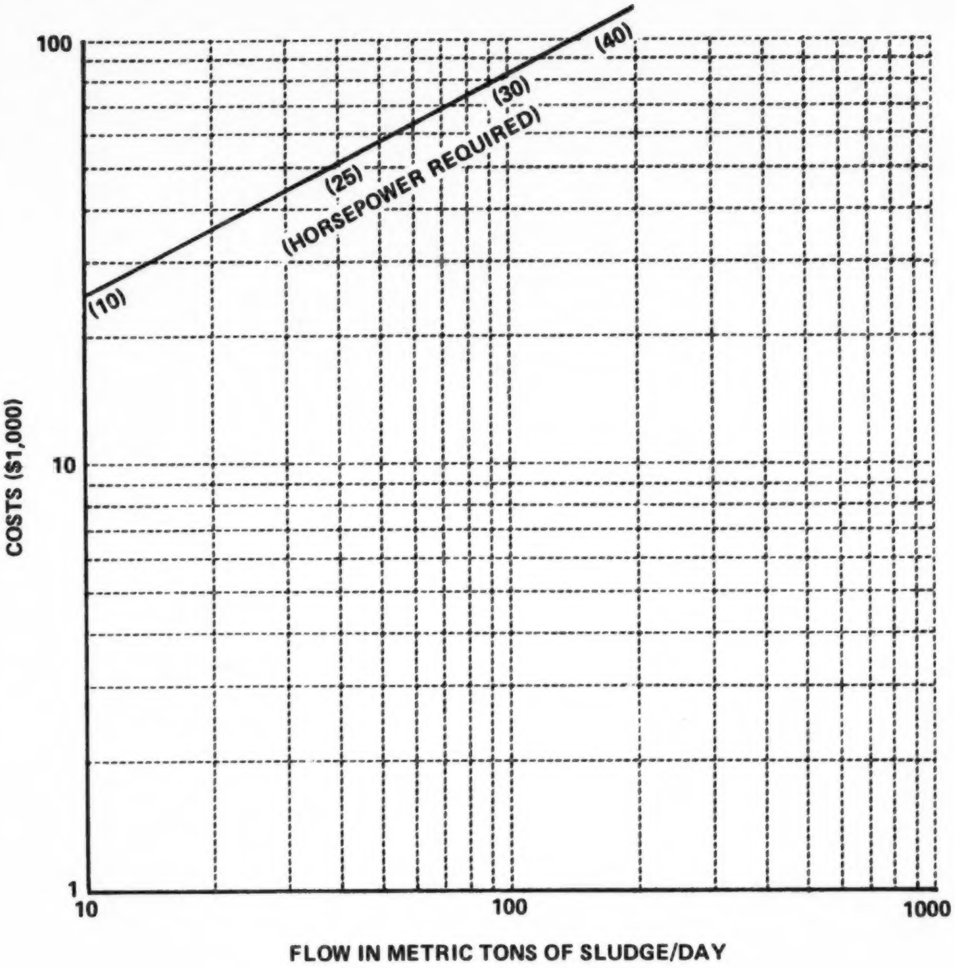

Figure A-1. CENTRIFUGE COSTS

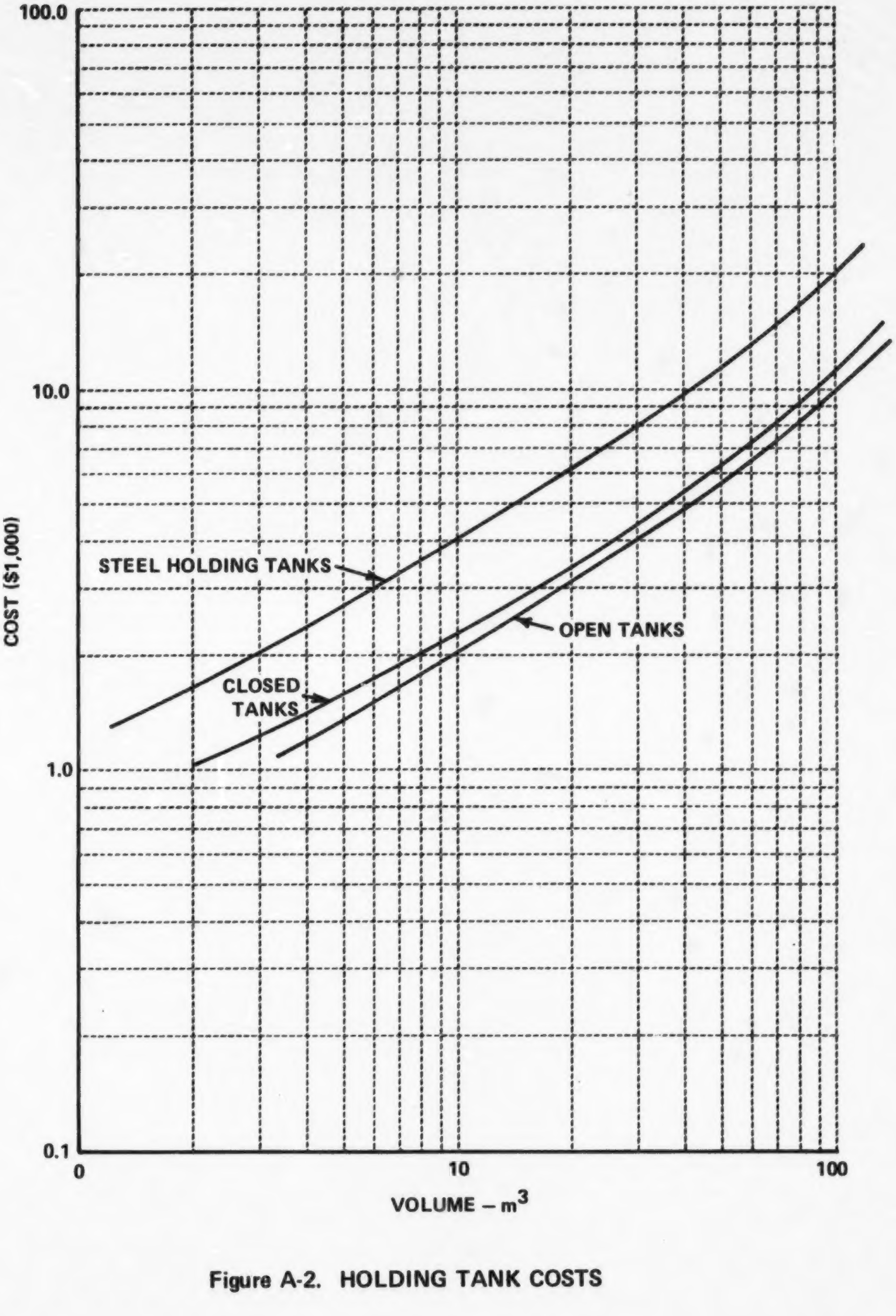

Figure A-2. HOLDING TANK COSTS

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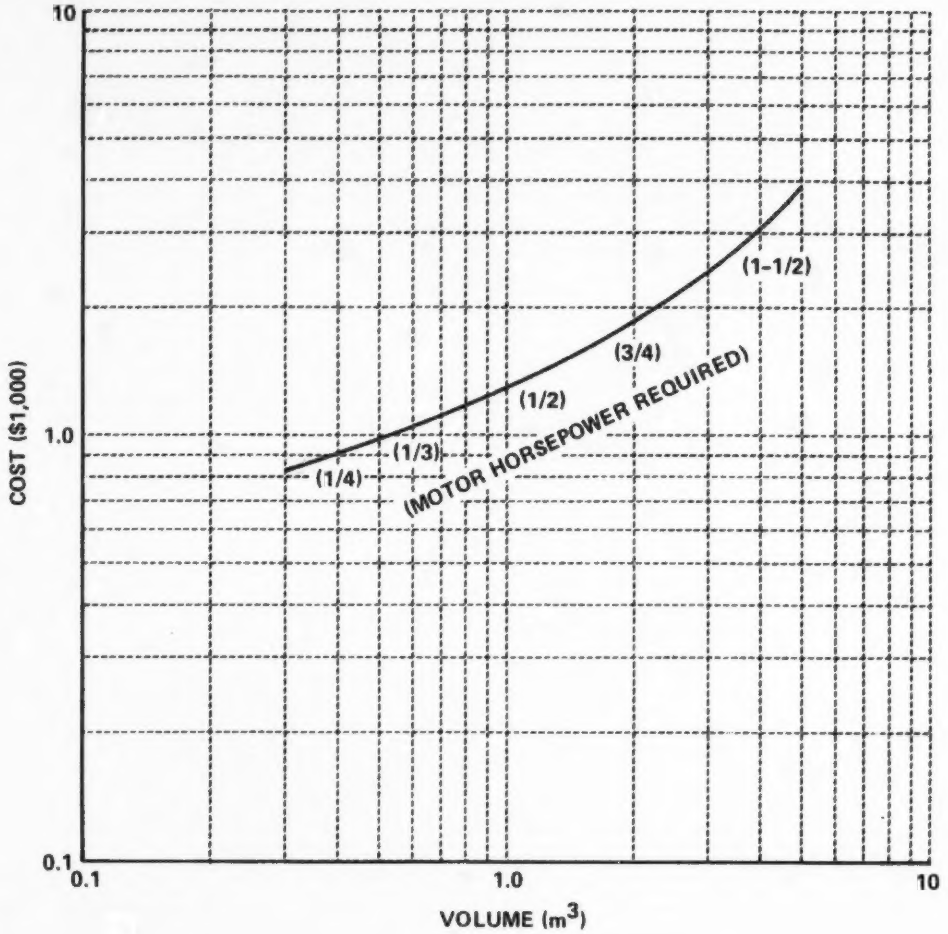

Figure A-3. MIXING-TANK COSTS

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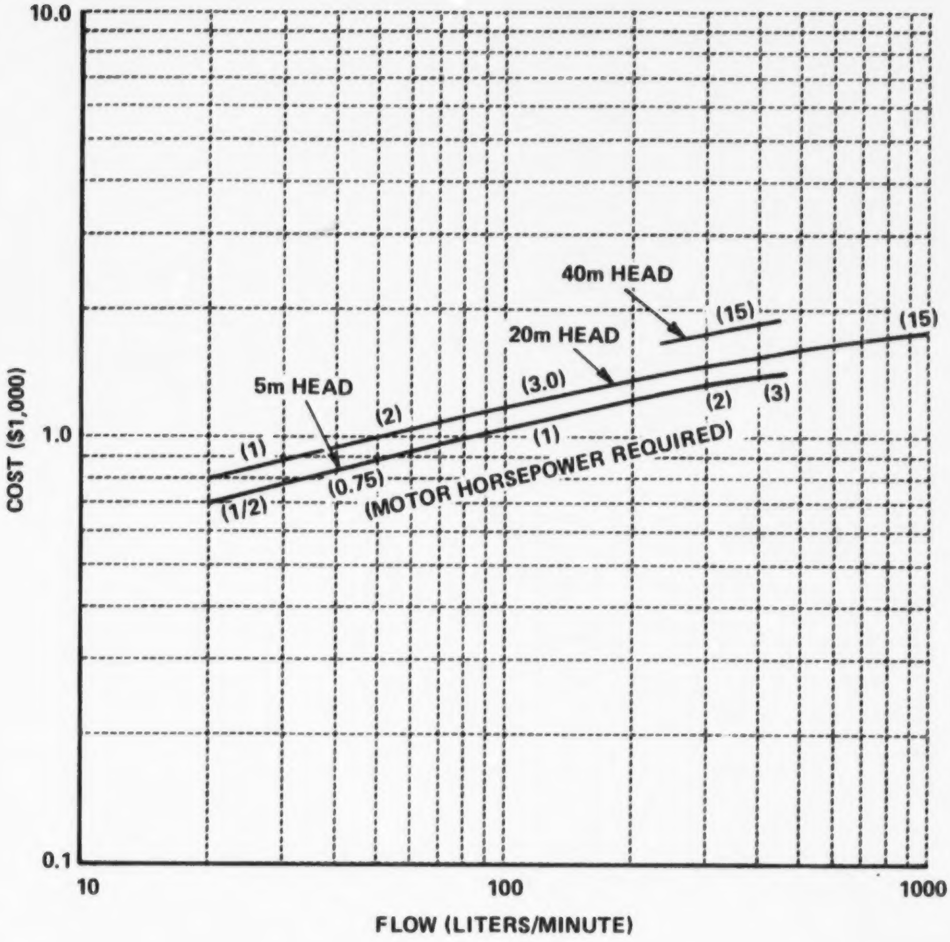

Figure A-4. COST OF SLURRY/SLUDGE PUMPS

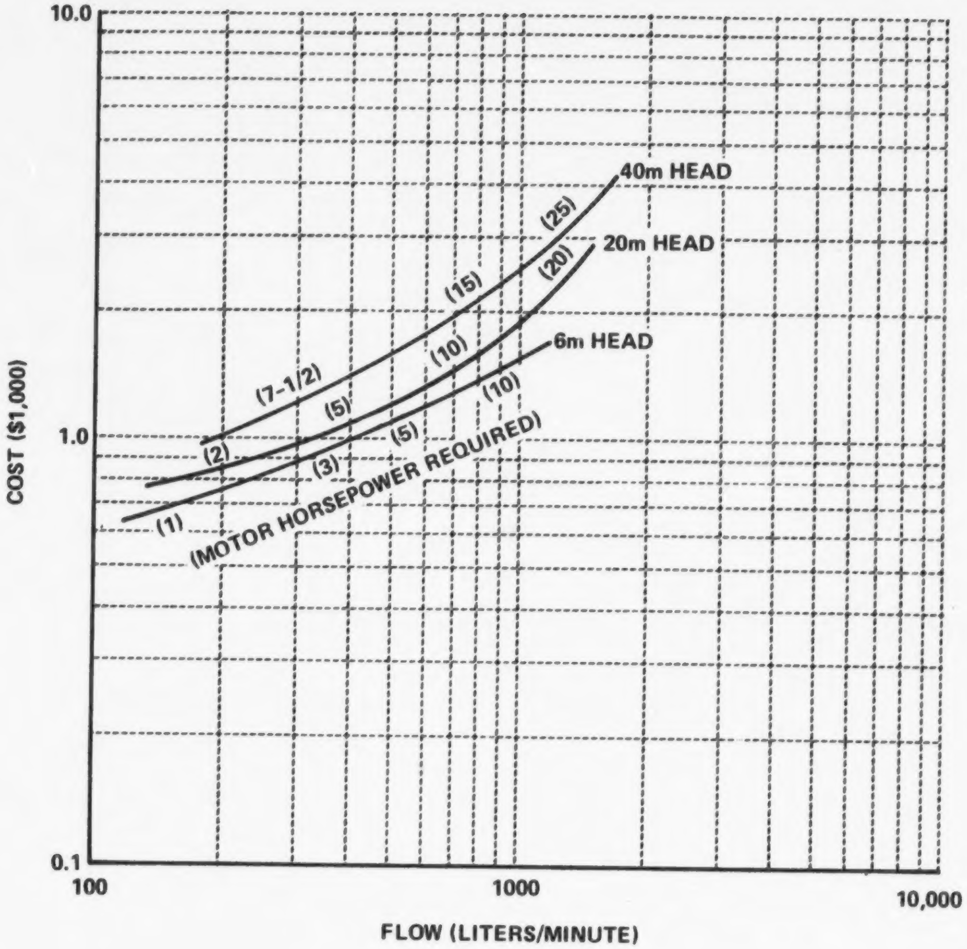

Figure A-5. COST OF CENTRIFUGAL PUMPS

Piping. Installed costs of two types of pipes are shown in Table A-1. The basic costs are increased by 20% to account for ancillary fittings, such as connectors, Ts, and valves.

Installation. Many factors can affect the cost of installing equipment. These include wage rates, whether the job is performed by outside contractors or regular employees, and site-dependent conditions (e.g. availability of sufficient electrical service).

Varying installation cost factors are used, ranging from 75 to 200% of equipment costs. For example, equipment which is delivered fully assembled, such as centrifuges is assigned a 75% installation cost. A higher percentage is applied for equipment which must be erected on-site, such as thickeners and kilns.

Table A-1 Installed Pipe Costs

Type	Diameter (cm)	Cost/Meter
Plastic, Fiberglass Reinforced	5	$24
	7.5	32
	10	38
	15	66
	20	110
Steel, Black, Schedule 40, Threaded	2.5	13
	5	21
	7.5	36
	10	48
	15	98

Contingency and Contractor's Fee. This cost is computed as 20% of the sum of the costs for facilities and equipment including installation.[4]

Annual Costs

Amortization

Annual depreciation and capital costs are

$$C_A = \frac{B(r)\ (1+r)^n}{(1+r)^n - 1}$$

where C_A = Annual cost

B = Initial amount invested

r = Annual interest rate

n = Useful life in years

The computed cost is often referred to as the capital recovery factor. It essentially represents the sum of the interest cost and depreciation.

An interest rate of 10% is used. The expected useful life of facilities and equipment is 10 years.[4] No residual or salvage value is assumed.

Operations and Maintenance

General. Plant operations are based on an assumed 350 days per year.

Operating Personnel. Personnel costs are based on an hourly rate of $13.50. This includes fringe benefits, overhead and supervision. Personnel are assigned for specific activities as required.

Repair and Maintenance. The cost of these activities is calculated as 4% of capital costs.[4]

Materials. The materials employed in the pretreatment processes and their costs are shown below. The costs include the basic material price plus estimated delivery costs.[2]

Coke breeze *	$ 50/metric ton	($ 45/s. ton)
Calcium chloride	105/metric ton	(95/s. ton)
Chlorine	150/metric ton	(136/s. ton)
Scrap iron	75/metric ton	(68/s. ton)
Hydrated lime	55/metric ton	(50/s. ton)

* Calspan estimate

Caustic soda	210/metric ton	(191/s. ton)
Pebble lime	50/metric ton	(45/s. ton)
Sodium Sulfide	300/metric ton	(273/s. ton)
Process water	0.08/m^3	(0.30/1,000 gal)
Polyelectrolyte*	$2/kg	(0.90/lb)

The following material costs are used to compute the value of recovered material. The costs exclude transportation costs.[2,3]

Potassium chloride	$ 64/metric ton	($ 58/s. ton)
Scrap copper	1,120/metric ton	(1,020/s. ton)
Copper	1,500/metric ton	(1,360/s. ton)
Aluminum	1,056/metric ton	(960/s. ton)
Lead	616/metric ton	(560/s. ton)
Zinc	814/metric ton	(740/s. ton)
Iron Pellets**	20/metric ton	(18/s. ton)
Rutile**	230/metric ton	(210/s. ton)

Waste Disposal. The sanitary and chemical landfill costs described in Part II are used as applicable. A charge of $1/metric ton ($0.90) is used for short-haul intra-plant transport of waste that is recycled.

Taxes and Insurance. These costs are included as $5 of the capital cost.[4]

Energy. Electrical-costs are based on the cost per horsepower-year computed as follows:

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*Calspan estimate

**Calspan estimate based on communications with operating plants.

$$C_y = 1.1 \left(\frac{HP}{E \times P} \times 0.7457 \times H_r \times C_{kW}\right)$$

Where C_y = Cost

HP = Total horsepower rating of motors (1 hp = 0.7457 kW)

E = Efficiency factor (0.9)

P = Power factor (0.9)

H_r = Annual operating hours (as applicable)

C_{kW} = Cost per kilowatt-hour of electricity (\$0.03)

1.1 = factor used for miscellaneous heating and lighting.

[4] Steam cost is calculated at \$4 per 10^6 Btu's; fuel cost at \$2 per 10^6 Btu's.

REFERENCES

APPENDIX A

(1) Building Construction Cost Data 1976, Robert Snow Means Company, Inc.

(2) Chemical Marketing Reporter, November 29, 1976.

(3) Wall Street Journal, January 27, 1977.

(4) Tarnay, A.G., EPA, (OSWMP) Letter Dated October 20, 1976 to Calspan Corporation.

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